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THE APPLICATION OF FUZZY LOGIC TO SUPPORT CUSTOMER RELATIONSHIP MANAGEMENT

DIPLOMOVÁ PRÁCE
MASTER'S THESIS

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Theoretical Background
Problem analysis and Current Situation
Proposals and Contribution of Suggested Solutions
Conclusion
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Appendices

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BOJADZIEV, G. a M. BOJADZIEV. Fuzzy Logic for Business, Finance, and Management. 2nd. World Scientific Publishing Company, 2007. 252 s. ISBN 981-270-649-6.
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ABSTRACT

The master's thesis focuses on application of fundamental principle of Fuzzy Logic to predict the selection of customers for direct marketing campaigns by incorporating fuzzy approach. A fuzzy model is proposed for selection of customers who should be targeted for sale of subscription schemes. Selection criteria are formulated on the basis of customer's age, customer's balance, marital status, existence of loan, output of previous contact and duration in the seconds on the phone.

ABSTRAKT

Diplomová práce se zaměřuje na aplikaci základních principů fuzzy logiky pro pro kampaň přímého marketingu vybraných zákazníků. Fuzzy model je navržený pro určení zákazníků, kteří by měli být cíleni na prodej bankovního produktu. Kritéria výběru jsou určena na bázi klientova věku, množství prostředků na učtu, stavu, existence půjček, výstupu z posledního kontaktu a doba hovoru v sekundách.

KEYWORDS

Customer relationship management, fuzzy logic, marketing, business strategy, sales, customer service

KLÍČOVÁ SLOVA

Řízení vztahů se zákazníky, fuzzy logika, marketing, byznys strategie, prodej, služby zákazníkům

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Bc. Huy Nguyen

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INTRODUCTION

Due to globalisation, development of technology and variety of communication chains, competition between organisations have become more ambitious than before. The key to keep company‘s profitability is to have a sufficient Customer Relationship Management (CRM). The most crucial objective of CRM is to maximize the lifetime profits from a customer to a company. It is worth noting that in recent analysis showed that existing customers are cheaper to maintain in terms of costs and they create a significant amount of profit. Attract a new customer costs more than retain an existing customer and retained customers are good candidates for cross selling. It is necessary to point out that for these reasons many companies focus on consumer retention as the most important business activities.

The basis of fuzzy logic is the basis for human communication. This observation underpins many of the other facts and statements about fuzzy logic. The last statement is perhaps the most useful and deserves more of discussion. Common language which is used by ordinary masses on a daily basis has originated in hundreds of years of human history. This has evolved and been made more efficient and easy for use. Sentences written in common language is used for efficient communication. We are generally unaware of this because ordinary language is something we use every day. Since fuzzy logic is built a top the structures of qualitative description which are used in everyday language, fuzzy logic is easy to use and understand. Fuzzy logic is used by researchers to quantify generic data. Until now generic information cannot be measured. How will one decide how worthwhile it will be visiting any general store for purchasing goods? The best quality, best place, good offer are just not enough to help us in taking a decision, unless these attributes are measurable that is how good, how best it is. The uncertain information or imprecise data cannot be used for any task.

1 PROBLEM STATEMENT AND USED METHODS

1.1 Problem statement

The aim of this paper is to describe the design, build up and implementation of fuzzy based selection strategy software for targeting of potential customers for product subscription. The specific objective of this study was to investigate fuzzy set theory to shape from imprecise, unclear and fuzzy information expert system which support decision making by simplify output. This expert system systematically reviews the significant amount of data, aiming to provide enhanced, faster, smarter decision making for human element. Data for this study were collected using selected, relevant and useful inputs to execute the purpose of this paper. The fuzzy based selection system includes designing the expert system, selecting the membership function, input, output and a fuzzy rule base. Data for this study were collected using real-world data from a Portugal bank marketing campaign related with bank deposit subscription.

1.2 The main objective

The fuzzy logic expert system for targeting customers for subscribing fixed deposits, the following six input is taken for consideration i.e. age, average yearly balance , marital status, existence of loan, previous contact outcome, duration of contact. This data reflects the degree of vagueness in the information furnished by the customer and collected by the banks from various sources. Fuzzy logic is a strong tool that deals with decision making and human reasoning involving inaccuracy, uncertainty, vagueness and approximation. One can apply fuzzy logic that helps in quantifying the contribution of a set of information to various parameters in terms of fuzzy membership. Fuzzy logic emerged as an attractive tool for various applications ranging from decision analysis, time series prediction, finance, traffic control, automobile speed control, pattern recognition, robotics and earthquake detections etc.

2 DEFINITION OF CUSTOMER RELATIONSHIP MANAGEMENT

Customer Relationship Management (CRM) is a comprehensive approach for creating, maintaining and expanding customer relationships with a strategy which sets the direction for an organisation. It means to understand what customers want and need in today's economy where organisations may never meet customers in a person-to-person sense. CRM is about creating the feel of high touch in a technological era (Anderson, et al., 2001). Customers are changing. They are becoming more difficult to catch and hold onto due to the access to more information about goods and services and choose to communicate in new ways. And effective communication across all customer touch-points is what, increasingly, CRM is all about (Peel, 2002).

Customer Relationship management is the strongest and the most effective approach in maintaining and creating relationships with customers. Figure 1 shows that customer relationship management is not only pure business but also ideate powerful personal bonding within people. Improvement of this class of bonding drives the business to new levels of success. Once this personal and emotional connection is built, it is very clear for any organization to identify the actual needs of customer and help them to serve them in a better way. It is a acceptance that more the sophisticated strategies involved in implementing the customer relationship management, the more strong and productive is the business. Most of the businesses have dedicated world class tools for maintaining CRM systems into their organisation (Management Study Guide, 2013). Many corporations are increasingly adopting CRM as a means to forge their competitive advantage – the ability to understand individual customer needs, and therefore to manage their marketing efforts more efficiently (Kumar, et al., 2012).

Figure 1: CRM is an approach to managing a company's interaction (Emma George, 2014)

There are three main essential features to consider when aligning your business towards a customer relationship format:

- The first is to do with retention. Imagine that compay never to get another new customer, this would probably be a horrifying thought for most businesses, but when consider it carefully you would realise that if you just kept the customers that you have then you would probably be able to grow and prosper in much the same way as you are now. There are indeed exceptions. Most businesses only have a small percentage of the share of each of their customers. In addition most businesses will lose current customers at a rate of somewhere between 15-50 per cent per annum.

- The second stage is to expand customer potential: turning that one off occasional customer into a higher spending, more frequent, referring advocate.

- The third element of customer relationship management and perhaps the most questionable one is the de-selection of customers. If a company or organisation were to put more of its efforts into its existing customers it would make sense that

it did this with customers that had the greatest potential. This means that at some point, it has to start to lose those customers who are not ones that offer long-term future value. This might be because of transaction costs, the value of a customer or the cost of transacting or dealing with that customer or customer group (Roberts-Phelps, 2001).

Businessmen have come to acknowledge the impact of the "Pareto Principle" on the survival of their organisations. Pareto, a late 19th century Italian economist and sociologist, recognized that a majority of his nation's wealth was held by a minority of the population. The Pareto Principle is also referred to as the 80–20 Rule, suggesting that 80 percent of the wealth was held by 20 percent of the population. This principle is widely confirm in marketing data. Figure 2 shows a fictional product in which just 20 percent of the users generate 50 percent of the profits. But as dire as Pareto's prescription is, the everyday reality is probably even more harsh. It's likely (especially in services) that 60 percent of a business's customers could actually be generating negative profits taking the business money. Given this fact, one can easily see how the mandate of keeping all the customers possible can actually be a recipe for failure (Keiningham, et al., 2005).

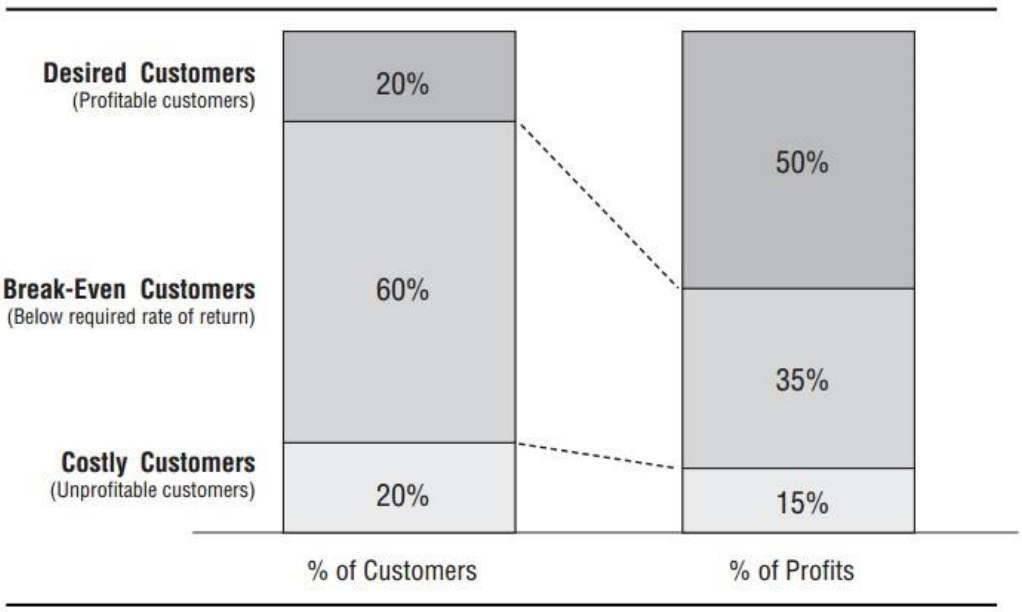

Figure 2: Pareto Principle (Keiningham, et al., 2005)

The value of retention is significantly important for a company's growth and according to Bain and Co., a 5% increase in customer retention can increase a company's profitability by 75%. And if those numbers are not impress enough, Gartner Group statistics show us that 80% of your company's future revenue will come from just 20% of your existing customers (Lawrence, 2012). It costs five times more to acquire a customer than to retain a customer (Keiningham, et al., 2005).

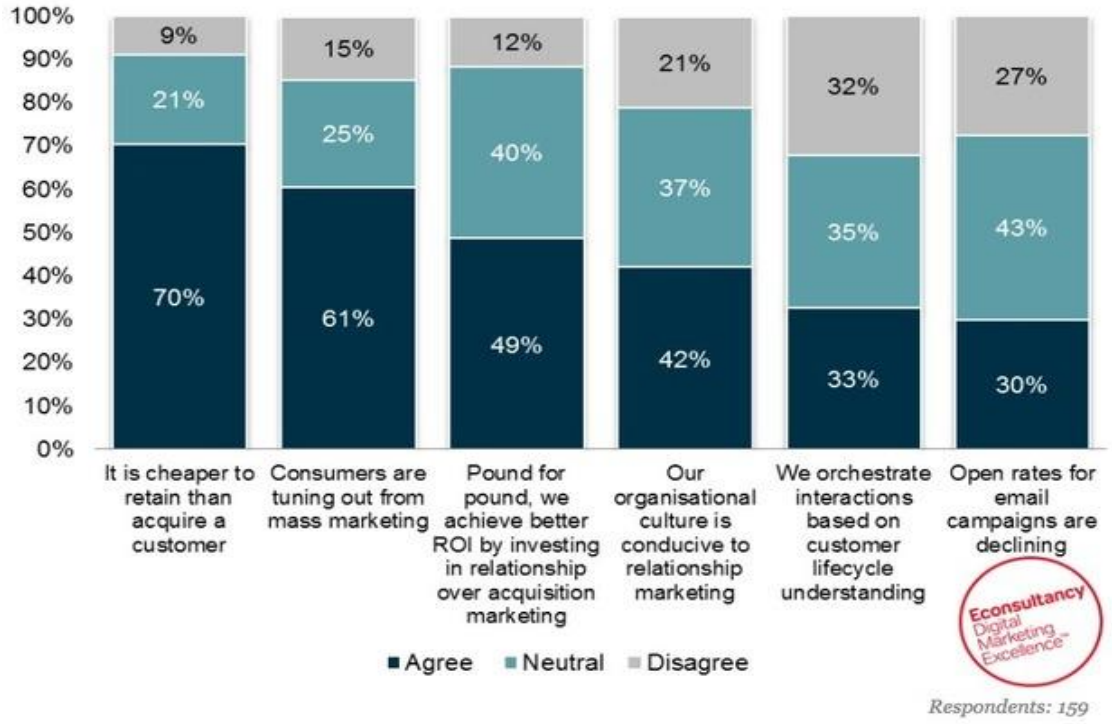

Figure 3: Oursocialtimes research (Brynley-Jones, 2013).

According a research from Oursocialtimes.com 70% of companies say it's cheaper to retain a customer than acquire one and 49% say that, pound for pound, they achieve better ROI by investing in relationship marketing over acquisition marketing (Brynley-Jones, 2013).

2.1 What is needed to implement CRM strategies

The implementation of a CRM strategy is a continuous process of developing and executing a series of small projects aimed at satisfying the business needs and increasing the value proposition to customers. Three essential ingredients are needed to implement CRM strategies from a modeling perspective: database, technology, and metrics.

2.1.1 Database

The database is the essential to any CRM planning. Companies gain information to store, analyse, and make marketing decisions based on the results of data analysis. This part provides a basic overview of the categories of databases and the sources from which data can be collected.

2.1.2 Categories of databases

There are many types of databases and different ways to categorize them. This can be done according to firms' main business function, information contents, underlying marketing activities, or database technology. As the focus of this paper is on data modelling of two types of databases in detail: the transaction related database and the customer database.

- Transaction-related database. This database refers to all the information associated with the transactions that customers have made. Examples of this type of information are:

    a) What transactions have the customers conducted?
    b) What type of product was bought?
    c) How frequent is this type of product purchased by the customer?
    d) How much was spent in the transaction?

- Customer database. This database is essentially a collection of information about a company‘s customers. In general, the following information may be included in customer databases:

    a) Basic information: name, address, post code, and telephone number.
    b) Demographic information: age, gender, marital status, education, number of people in household, income, and so on.
    c) Psychographic information: values, activities, interests, preferences, and so on.
    d) Other relevant information: inquiries and referrals, satisfaction, loyalty.

Over a period of time, databases will begin to consits of prospects who have yet to be acquired, along with active and inactive customers. Information on prospects and active and inactive customers are valuable to marketers and should be included in customer databases. While data from active customers help marketers learn what has been done well, data from inactive customers help marketers to identify what needs to be upgraded, and data from prospects who were not acquired show the effectiveness of acquisition efforts and the type of customer the firm has a hard time acquiring. For inactive customers, the following additional information would be valuable to document:

- How long have the customers been inactive and active?
- What was their purchasing pattern when they were active?
- How much money did they spend?
- How were they initially acquired?
- Why are they inactive?

For prospects who were not acquired, the following information would be important to document:

- How much was spent on the prospects?
- Is the profile of the prospects that were not acquired different from the profile of prospects that were acquired?
- What types of prospects should the company target in the future? Why did these prospects choose not to adopt?

2.1.3 Sources of databases

Administrators acquire databases from two main sources: primary data sources and secondary data sources. Figure 4 shows a concise summary of available data sources as primary and secondary data sources.

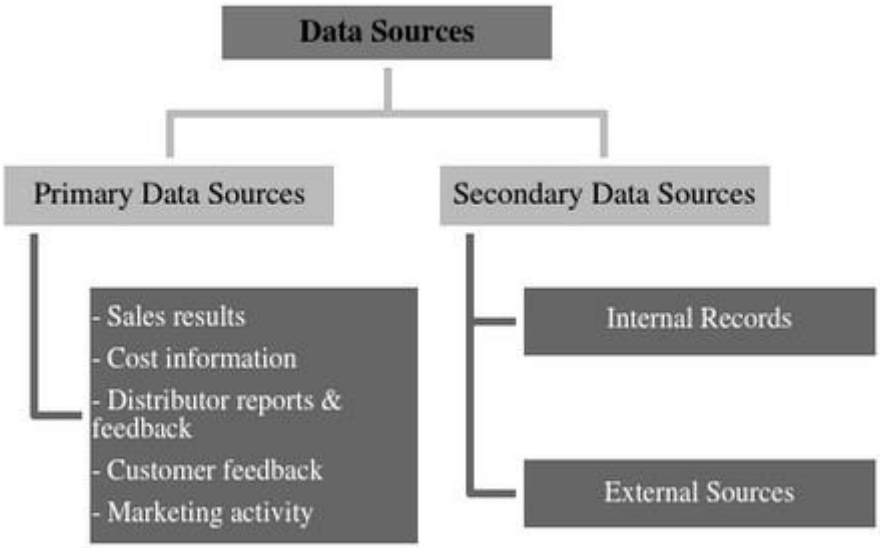

Figure 4: Data Sources Source: (Kumar, et al., 2012)

Primary data are original data collected directly by the focal firm that are not available or cannot be derived from any other sources. Primary data collection is usually conducted internal in the forms of experiments or survey methods such as questionnaires, interviews, or measurement. Although primary data selection is a costly and time-consuming process, it is sometimes necessary for managers to obtain primary data if the required data cannot be obtained elsewhere or if the reliability of those data cannot be determined even when they can be obtained from other sources. Otherwise, secondary data are data that have already been made available or published in any form. There are two types of secondary data sources: internal records and external sources. Information from internal records is the primary information that the firm obtains straight from its daily business operations (e.g., sales results, cost information, etc.), from customer feedback, or from its marketing activities. This internal information usually comes from various departments inside the company, such as the internal marketing research department, sales analysis group, accounting department, or corporate strategic planning unit. Information from external sources is the secondary information obtained from non-internal sources which can be divided to:

- Published data sources. These data are made available in electronic or printed out form from official sources such as government organizations, trade associations, periodicals, newspapers, books, annual reports, and private studies.

- Standardized sources of marketing data sources. In addition published data sources, managers can look at information available from a wide variety of sources from retail stores, warehouses, scanner-based systems, and so on that help provide the managers with a full picture of the market situation of a product category or brand.

- Internet. The Internet is an important and useful source of secondary information. Given the rapid growth of social media activities, managers are interested in both official and non-official information obtained from customers' activities on the Internet, such as customer feedback, reviews about the firm's products and services, etc.

The use of databases for collecting, storing, and analysing customer data has been crucial for innovations in the CRM process. Nevertheless, technology improvements have been a key driver in making database innovations and other CRM processes accessible, user-friendly, and affordable for firms.

2.2 Technology

An important factor that drives CRM development in its current stage is the fast growth of technology. CRM implementation in this manenr has evolved into a user-friendly, flexible, low-cost, and high-tech process. In particular, the three main components of CRM technologies, namely, customer touch points, CRM applications, and data storage technology, have gone through significant advancement. Customer touch points have moved away from the traditional face-to-face communication between customers and salespeople. With the introduction of Voice over Internet Protocol (VoIP) technology, speech recognition technology, and social networking applications, interactions with customers can be in various forms of Web-based (e-mail, web sites, Facebook, Twitter, etc.) and phone-based (telesales, automatic voice recognition systems, etc.) interactions

rather than a physical social interaction. Further, with the widespread use of the Internet and the growth smart phones, CRM applications are now offered in many forms, such as traditional ERP (Enterprise Resource Planning) systems and mobile or Web-based online portals. All these developments and advancements have two key implications for CRM analysts in the area of modelling and data analysis. First, as more data become available, the ways of obtaining them have also increased enormously. This has given rise to creative ways of collecting customer data and adding more data points about a particular customer, by that creating a more complete picture of the customer. Second, while massive databases add to the knowledge and resource pool of the organization, they also pose significant modelling challenges regarding the use of suitable data to collect relevant managerial insights.

2.3 Metrics

The old saying 'You cannot manage what you cannot measure' is most appropriate where metrics are concerned. Metrics support companies track and evaluate their performance and, more importantly, evaluate the returns on their CRM initiatives. In the process of implementing CRM, managers have to deal with a significant amount of data with the ultimate goal of evaluating managerial performances based on the value that each individual customer brings to the firm. In order to record and quantify those evaluations, managers need a set of indicators that scope customer values. Metrics perform this role. The benefits of developing and using metrics are meaningful to companies.
Some of the key benefits that accumulate to the firm are:

a) sturdy control over business processes and CRM activities,
b) means to measure development in revenues, costs, and profits,
c) gauges and targets to attain certain levels of performance,
d) gauges on return on investment (ROI),
e) aid in the acquisition and retention, preventing churn, and assisting win-back of profitable customers, and
f) realigning marketing resources to maximize customer value.

There are two expansive categories of metrics, brand-level and customer-level. Brand-level metrics are metrics that measure the brand's competitiveness in the market, such as market share, customer equity, sales growth, and etc. Customer-level metrics break down those brand-level metrics to the individual customer, such as acquisition cost per customer, size of wallet, and etc. When mixed, brand-level and customer-level metrics give managers a complete picture of how the firm or the brand fares in the market, as well as how its customer needs differ on an individual level, and how to leverage these differences to enhance the overall competitiveness of the firm. Table 1 presents some usually used metrics at both brand-level and customer-level. At this point, the table is meant to provide a general view of the types of CRM metrics available. In the subsequent chapters, we will delve further with detailed discussions about these metrics.

Table 1: Popular CRM metrics (Kumar, et al., 2012)

Metric	Definition	Use of metric
1. Market share	The percentage of a firm's sales to the sales of all firms in a given market	Brand-level
2. Sales growth	The increase or decrease in sales volume or sale value in a given period compared to that in the previous period	Brand-level
3. Acquisition rate	The proportion of prospects converted to customers	Brand-level
4. Acquisition cost	The acquisition spending of a focal firm per prospect acquired	Brand-level and customer-level
5. Retention rate	The average likelihood that a customer *makes a repurchase* from the focal firm in period *t*, given that this customer has purchased in the last period $t - 1$	Brand-level and customer-level
6. Defection rate	The average likelihood that a customer *defects* from the focal firm in period *t*, given that this customer has purchased in the last period $t - 1$	Brand-level and customer-level
7. Survival rate	The ratio of customers who continue to remain as customers (survive) until a period *t* from the beginning of observing these customers	Brand-level
8. Average lifetime duration	The average duration customers continue to remain as customers	Brand-level
9. P-active	The probability of a customer making a repurchase (being active) in a given period	Customer-level
10. Win-back rate	The ratio of acquisition of customers who had been lost in an earlier period	Brand-level

The important thing for an organisation to remember is that determining which metric(s) to measure and manage should depend on how each metric relates to the desired short-term or long-term goals. If the metric(s) chosen cannot be quantifiably related to desired goals measures such as profitability and shareholder value, the metric(s) are not generally worth measuring and managing.

2.4 Analytical methods

Data, technology, and performance metrics connect to provide interesting insights into both the brand and the customer. Nevertheless, in order to maximize the performance metrics, one has to understand the drivers/levers affecting them. E.g. if a firm wants to maximize CLV, one proven strategy is to optimally allocate the marketing resources to each customer. However, this would not be possible if there were no statistical model created to link marketing activities to CLV. Thus, statistical models provide the essential function of creating the linkage between performance metrics and the possible drivers/levers. In this paper, we create many linkages through statistical models to help acquire, retain, and win back profitable customers as well as identifying customer propensity to churn. With the arrival of higher computing power, the use of statistical tools is becoming a common phenomenon in all organizations.

2.5 Using CRM

Up till now we have seen the basics of CRM and the role of databases, technology, and metrics in achieving CRM initiatives. While the connection between the components for ensuring CRM success is fairly straightforward, the question for marketers is in generating the metrics. With improvement in data collection and database technologies, identifying the correct approach to employ for generating metrics could determine the success or failure of a CRM campaign. How can marketers generate metrics that can help them in managerial decision making? Using statistical methods and models, it is possible to reduce volumes of data to easy-to-use metrics that can help in evaluating business performance.

The following chapters discuss in detail fuzzy logic statistical methods used in designing CRM campaigns customer retention, preventing customer churn, and customer win-back. The model discussed in these chapters to address specific marketing challenges can then be used in comprehensive metrics to measure marketing and business performance (Kumar, et al., 2012).

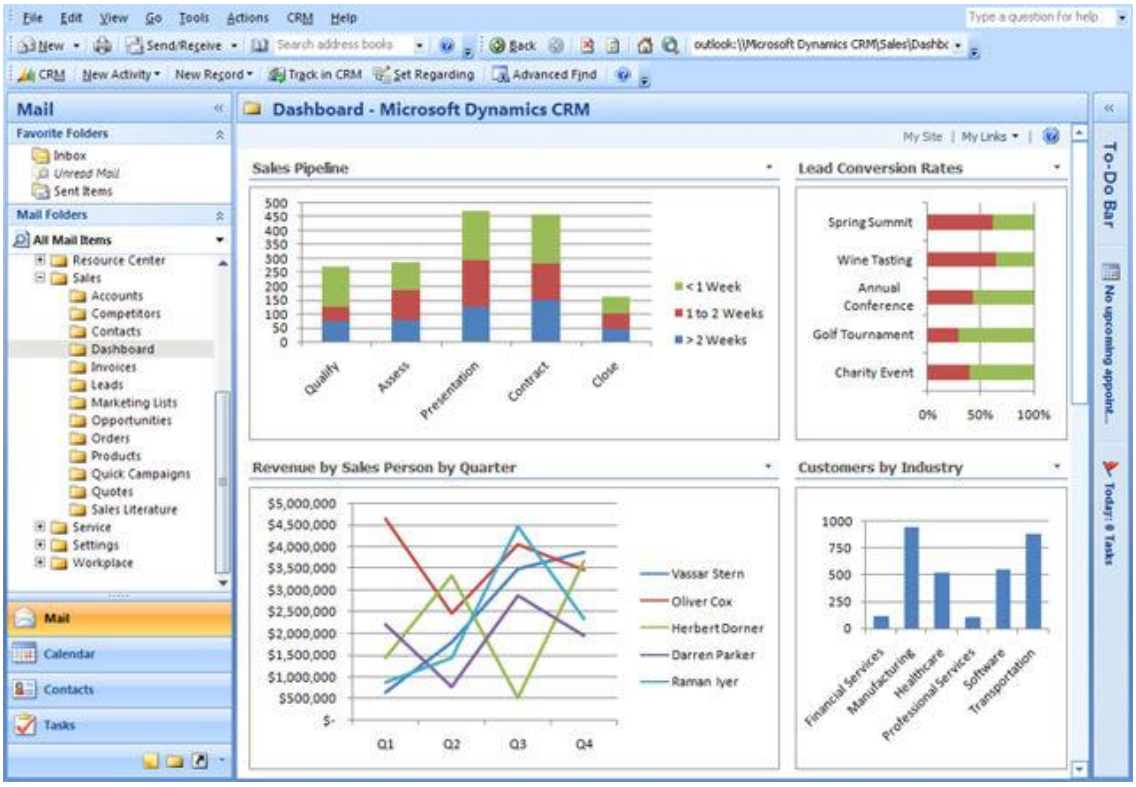

Figure 5: Example of CRM by Microsoft (Living Business Online Inc., 2014)

„Positive customer experience is an increasingly important ingredient for companies to win and retain customers. Customer engagement helps companies deliver amazing customer experiences by building long-term customer relationships that are personalized, proactive, and predictive across marketing, sales, and service.“ (Microsoft, 2015)

3 DEFINITION OF FUZZY LOGIC

Traditionally, classical (two-valued) logic deals with propositions that are either true or false. In many-valued logic, a generalization of the classical logic, the propositions have more than two truth values. Fuzzy logic is an extension of the many-valued logic in the sense of incorporating fuzzy sets and fuzzy relations as tools in to the system of many-valued logic. Fuzzy logic provides a methodology for dealing with linguistic variables and describing modifiers like very, fairly, not, etc. Fuzzy logic facilitates common sense reasoning with imprecise and vague propositions dealing with natural language and serves as a basis for decision analysis and control actions (Bojadziev, et al., 2007).

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. Fuzzy logic includes 0 and 1 as extreme cases of truth (or "the state of matters" or "fact") but also includes the various states of truth in between so that, for example, the result of a comparison between two things could be not "tall" or "short" but ".38 of tallness." Fuzzy logic seems closer to the way our brains work. We aggregate data and form a number of partial truths which we aggregate further into higher truths which in turn, when certain thresholds are exceeded, cause certain further results such as motor reaction. A similar kind of process is used in artificial computer neural network and expert systems. It may help to see fuzzy logic as the way reasoning really works and binary or Boolean logic is simply a special case of it. (Rouse, 2006)

The fuzzy logic system consists of three elementary steps: fuzzification, fuzzy inference and defuzzification (Dostál, 2013).

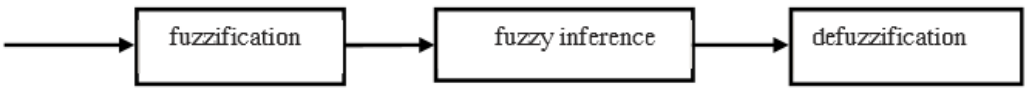

Figure 6: Three steps of fuzzy logic system (Dostál, 2013)

The process begins with first step called fuzzification where the data of natural language are transformed into numerical values. A classic examples of linguistic values can be no,

very low, low, medium, high, and very high risk. In addition, it is important to mention that amount of attributes are from three to seven. The degree of membership of attributes is formulated by mathematical functions (Dostál, 2013).

3.1 The Development of Fuzzy Logic

The idea of fuzzy logic was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s. Dr. Zadeh was working on the problem of computer understanding of natural language. He made significant advancement in the establishment of fuzzy logic as a scientific discipline. There is not a unique system of knowledge called fuzzy logic but a variety of methodologies proposing logical consideration of imperfect and vague knowledge. It is an active area of research with some topics still under discussion and debate. Fuzzy sets are a generalization of classical sets and infinite-valued logic is a generalization of classical logic. There is also a correspondence (isomorphism) between these two areas. Fuzzy logic uses as a major tool—fuzzy set theory. Basic mathematical ideas for fuzzy logic evolve from the infinite-valued logic, thus there is a link between both logics. Fuzzy logic can be considered as an extension of infinite-valued logic in the sense of incorporating fuzzy sets and fuzzy relations in to the system of infinite-valued logic (Bojadziev, et al., 2007).

3.1.1 Basic Concepts of Classical Logic

Here, some basic concepts of the classical 1 (mathematical) or two-valued logic are briefly reviewed. Propositions Aproposition, also called statement, is a declarative sentence that is logically either true (T) denoted by 1 or false (F) denoted by 0. The set $T = \{0, 1\}$ is called truth value set for the proposition. In other words a proposition maybe considered as a quantity which can assume one of two values: truth or falsity.

3.1.2 Many-Valued Logic

Since the time when in logic the principle every proposition is either true or false has been declared, there have always been some doubts about it. One reason for questioning the above principle is the difficulty arising with estimating truth values of propositions expressing future events, for instance tomorrow will rain. Future events are not yet true

or false. Their truth value is unknown; it will be determined when the events happen. The classical (two-valued) logic is not sufficient to describe the truth value of these type of events. Hence it looks natural to allow a third truth value other than pure truth or falsity which leads to a three-valued logic. Depending on how the third value is defined, several three-valued logics were introduced.

Suppose that a proposition has three truth values: true denoted by 1, false denoted by 0, and neutral or indeterminate denoted by $\frac{1}{2}$. They form the truth value set

$$T = \left\{0, \frac{1}{2}, 1\right\}$$

3.1.3 Fuzzy Logic

Natural language (like most other activities in life and indeed the universe) is not easily translated into the absolute terms of 0 and 1. (Whether everything is ultimately describable in binary terms is a philosophical question worth pursuing, but in practice much data we might want to feed a computer is in some state in between and so, frequently, are the results of computing.)

Fuzzy logic focuses on linguistic variables in natural language and aims to provide foundations for approximate reasoning with imprecise propositions. It reflects both the rightness and vagueness of natural language in common-sense reasoning. The relations between classical sets, classical logic, fuzzy sets (in particular fuzzy numbers), infinite-valued logic, and fuzzy logic are schematically shown on Figure 7. Major parts of fuzzy logic deal with linguistic variables and linguistic modifiers, propositional fuzzy logic, inferential rules, and approximate reasoning (Bojadziev, et al., 2007).

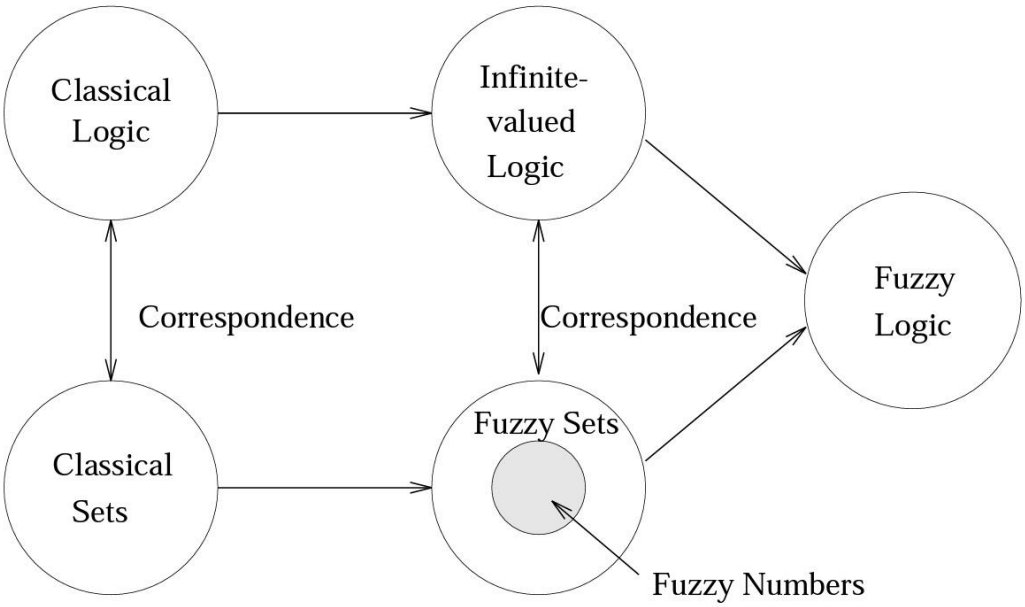

Figure 7: Fuzzy Logic Source: (Bojadziev, et al., 2007)

3.1.3.1 Linguistic Variables

Variables whose values are words or sentences in natural or artificial languages are called linguistic variables. To illustrate the concept of linguistic variable consider the word age in a natural language; it is a summary of the experience of enormously large number of individuals; it cannot be characterized precisely. Employing fuzzy sets (usually fuzzy numbers), we can describe age approximately. Age is a linguistic variable whose values are words like very young, young, middle age, old, very old. They are called terms or labels of the linguistic variable age and are expressed by fuzzy sets on a universal set U $\subset$ R + called also operating domain measured in years. It represents the base variable age. Each term is defined by an appropriate membership function.

3.2 The reasons to use Fuzzy Logic

In few last years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio option.

Here is a list of general aspects about fuzzy logic:

- Fuzzy logic is conceptually easy to understand. - The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive access without the far-reaching complexity.

- Fuzzy logic is flexible. - With any given system, it is easy to layer on more functionality without starting again from the beginning.

- Fuzzy logic is tolerant of imprecise data. - Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.

- Fuzzy logic can model nonlinear functions of arbitrary complexity. - You can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS), which are available in Fuzzy Logic Toolbox software.

- Fuzzy logic can be built on top of the experience of experts. - In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system.

- Fuzzy logic can be blended and used with conventional control techniques. - Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.

- Fuzzy logic is based on natural language. - The basis for fuzzy logic is the basis for human communication. This observation underlines many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use.

The last statement is perhaps the most important one and deserves more discussion. Natural language, which is used by ordinary people on a daily basis, has been shaped by thousands of years of human history to be convenient and efficient. Sentences written in ordinary language represent a triumph of efficient communication (The MathWorks, Inc., 2015). In this master’s thesis Matlab is used to achieve the objective.

4 MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modelling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran. The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

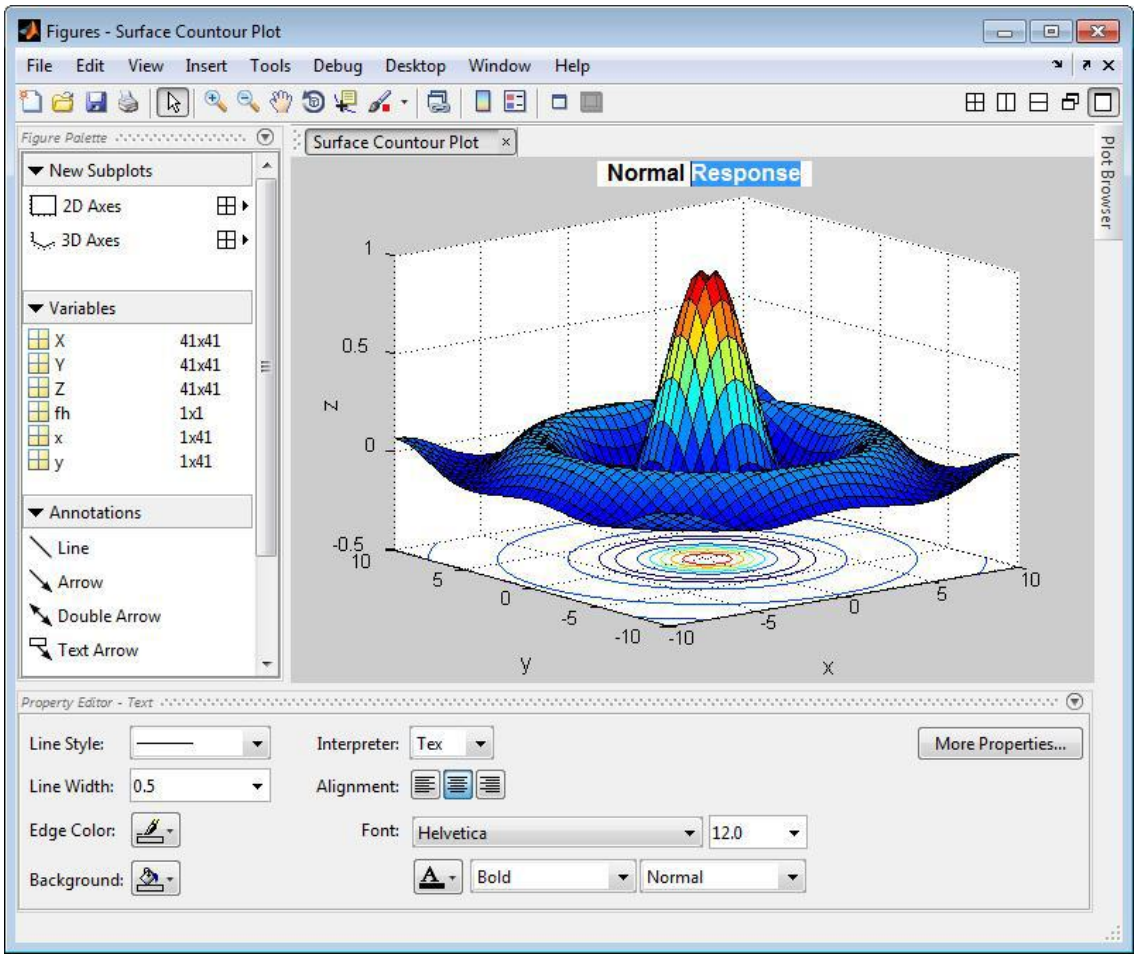

Figure 8: Matlab (The MathWorks, Inc., 2015)

MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

4.1 The MATLAB System

The MATLAB system consists of five main sector:

1. **The MATLAB language.**

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

2. **The MATLAB working environment.**

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

3. **Handle Graphics.**

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications.

4. **The MATLAB mathematical function library.**

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

5. **The MATLAB Application Program Interface (API).**

This is a library that allows you to write C and Fortran programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files (The MathWorks, Inc., 2015).

5 DEVELOPMENT OF FUZZY BASED CRM SYSTEM

The wide range of marketing campaigns over time has diminished its effect on the general public. Furthermore, the strong competition has led marketing managers to invest on selective directed campaigns with a rigorous selection of customers to be promoted to.

Such type of targeted campaigns can be accomplished by using techniques such as Data Mining and Business Intelligence. For this paper, real-world data was collected from a Portuguese marketing campaign connected with bank deposit subscription. The business goal is to find a model that can explain success of a contact, i.e. if the client subscribes the deposit which the company is advertising. Such model can increase campaign efficiency by identifying the main characteristics that affect success of the program, helping in a better management of the resources that are accessible (e.g. human effort, phone calls, time) and selection of a high quality and affordable set of potential buying (Fuzzy Based Decision Making for Promotional Marketing Campaigns, 2013).

5.1 Expert system

Expert system is a computer program that emulate the reasoning of a human expert or perform in an expert manner in a domain for which no human expert exists. They typically deal with uncertain and imprecise information. There are many sources of imprecision and uncertainty. The knowledge that they represent is not exactly in the same way that a humans's knowledge is imperfect. The facts of user-supplied information is also uncertain. An expert system is typically made up of at least three components: an inference engine, a knowledge base, and a global or working memory. The knowledge base contains the expert domain knowledge for use in the problem solving situations. The working memory is used as a scratch pad and to hold information gained from the user of the system. The inference uses the domain knowledge together with acquired information about a problem to provide an expert output.

Expert systems have modelled uncertainty and imprecision in various ways. They usually use some form of high level rules. Blind search of the solution space is dodged and high performance, approaching or surpassing an expert's, is obtained. Reasoning can be done by symbol manipulation (Kandel, 1991).

5.1.1 Fuzzy Based Expert CRM System

The fuzzy logic expert system is particularly useful in targeting customers for subscribing fixed deposits. Criteria for selection of input was the vagueness of the data and six following were included. Namely age, average yearly balance, marital status, existence of loan, previous contact outcome and duration of contact. As mentioned above fuzzy logic is a powerful tool to indicate and enhancing human inaccuracy reasoning.

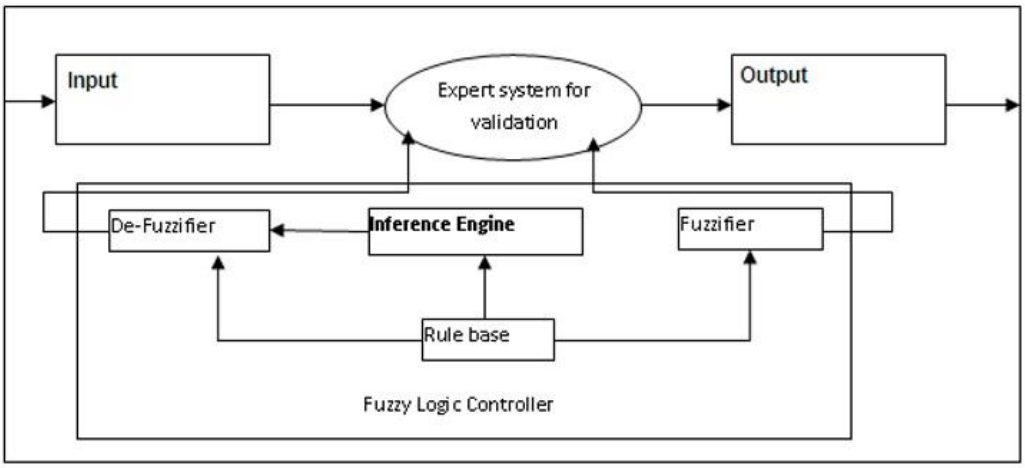

Figure 9: Fuzzy based expert system (Fuzzy Based Decision Making for Promotional Marketing Campaigns, 2013)

Author develop a fuzzy logic based expert system for selection of customers to be targeted for marketing calls for subscription Figure 9 shows the mechanism of such system. The fuzzy logic based expert system consists of four components: fuzzifier, inference engine, defuzzifier, and the rule base. The role of fuzzifier is to convert a crisp input variable into linguistic variables.

That is ready to be processed by the inference engine. The inference engine using the fuzzified inputs and the rules stored in the rule base process the incoming data and produces linguistic output. Once the output linguistic values are available, the defuzzifier produces the final crisp values from the output linguistic values. The validation process starts by entering two sets of data; one furnished by the customer and the other obtained by the banking marketing person reviewing the profile of the customer. The data is

obtained from direct marketing campaigns of a Portuguese banking institution. The marketing campaigns were based on phone calls in order to access if the product (bank term deposit) would be (or not) subscribed. This information is obtained from:

http://archive.ics.uci.edu/ml/datasets/Bank+Marketing

The information that is crucial in decision making of selecting the target customers is given higher weight age/impact factor. In the same way the values of the other inputs can be determined. The normalized values of these measures are used as inputs to the expert system. The degree of membership corresponding to a value of input is determined by the use of trapezoidal membership functions because of their simplicity and good result obtained by simulation. The membership functions are designed on the basis of the available information. Then the rule base is constructed which will be based on all the applicable input parameters and subsequently several rules are to be fired for each decision. The expert system's output is then defuzzified.

6 ALGORITHMS USING FUZZY APPROACH

The steps of the expert system are summarized below:

- Input. The crisp value of various input parameters like age, marital status, average yearly balance, existence of loan, previous contact outcome, duration of contact is obtained in the normalized form.

- Evaluate the main parameter. Determine the age, average yearly balance, and marital status, existence of loan, previous contact outcome and duration of contact.

- Fuzzify the crisp values of inputs. Through the use of membership functions defined for each fuzzy set for each linguistic variable, determine the degree of membership of a crisp value in each fuzzy set. Each of these ambiguity indices have been divided into different fuzzy sets.

- Fire the rule bases that correspond to these inputs. All expert systems which are based on fuzzy logic uses IF-THEN rules. The “IF” part is known as antecedent or premise, whereas the “THEN” part is termed as a consequence or conclusion. Since all the 6 inputs have number of fuzzy sets, therefore 648 (3x4x2x3x3x3) fuzzy decisions are to be fired. There are three outputs: Low Chance, High-Chance and Very-High-Chance category of customers who are taken into consideration for bank deposit subscription.

- Execute the inference engine. After the fuzzification of all crisp input values into their respective linguistic values, the inference engine will use the fuzzy rule base of the fuzzy expert system for deriving linguistic values for the intermediate and the output linguistic variables.

- Defuzzification. Now the defuzzification of the linguistic values of the output linguistic variables into crisp values is the final step of the fuzzy system. Different techniques available for defuzzification include center-of-maximum (CoM) and center-of-area (CoA). There are many other methods available for computing

crisp values from linguistic values. These are left-of maximum (LoM) or smallest-of-maximum (SoM), mean-of-maximum (MoM), right-ofmaximum (RoM) or largest-of maximum (LoM), bisector-of-area (BoA) and weighted average (WA)

- Output of the decisions of the expert system. In this case, the types of the outputs are: Less Chance, High-Chance and Very-High-Chance of customers for subscribing the bank deposit. Based on the output results the marketing manager targets the customer and makes marketing phone call for subscribing for deposit schemes.

Nevertheless, in principle, in all the fuzzy logic based expert system, we explore the implicit and explicit relationships within the system by mimicking human thinking and subsequently develop the optimal fuzzy rules as well as knowledge base.

Now we demonstrate the designing of the fuzzy decision support system, membership functions, fuzzy rule base, fuzzification and defuzzification. Fuzzy logic which is a very good tool is put to use in case of uncertain situations. Determination of input and output variables is the first step in designing the fuzzy decision support system. There are sixteen input variables and one output variable. After that, we have designed membership functions (MF) of all variables. The designed membership functions thus determine the membership of objects to fuzzy sets. Initially the input variables will be described along with their membership functions. Subsequently, the output variable with its membership functions will be introduced. Finally we will describe the rules used in the system, Fuzzification and Defuzzification process.

The sample data pertains to direct marketing - telemarketing campaigns of a Portuguese banking institution.
There is a dataset:

customer_data.csv

The goal is to predict if the client will subscribe to a term deposit.
The data is from a public data source. The author's fuzzy model has been developed purely based on the training data set. This data contains following 16 Input variables related to Customer Data:

Overall Input variables: Customer Data
1 - Age
2 - Job: type of job
3 - Marital: marital status
4 - Education
5 - Default: has credit in default?
6 - Balance: average yearly balance, in Euros
7 - Housing: has housing loan?
8 - Loan: has personal loan?
9 - Contact: contact communication type
10 - Day: last contact day of the month
11 - Month: last contact month of year
12 - Duration: last contact duration, in seconds
13 - Campaign: number of contacts performed during this campaign and for this client
14 - Pdays: number of days that passed by after the client was last contacted from a previous campaign
15 - Previous: number of contacts performed before this campaign and for this client
16 - Poutcome: outcome of the previous marketing campaign

Output Variable (desired target) is to predict whether customer subscribes for deposit scheme.

After consultation with the bank advisor Radim Sedláček the author came up with the reduced set of input variables that is relevant for designing the model. In the model designed six significant input variables were; age, average yearly balance, marital status, existence of loan, previous contact outcome, duration of contact.

6.1 Selected Input Variables

Data from previous chapter were consulted in terms of values of each possibility for the expert system.

6.1.1 Transform Matrix

A transformation matrix was used to support our expert system by adding the values to each option.

Table 2: Transformation matrix (Source: Author's own work)

	Age	Balance	High	Existence of Loan	Previous Contact Outcome	Duration of contact in seconds
1	less than 18	less than 15000	Single	0 - 20000	Success	0 - 300
2	18 - 35	15000 - 100000	Married	20000 - 100000	Failure	300 - 800
3	35 - 65	100000 - 200000		more than 100000		more than 800
4	65 - 100					

Table 3: Values of tranformation matrix (Source: Author's own work)

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact
1	20	30	70	90	100	40
2	80	60	50	70	50	70
3	100	100		40		100
4	40					

Table 4: Interval outputs (Source: Author's own work)

Interval	Output
560 - 448	Very high success
447 - 252	High success
251 - 230	Less success

6.1.2 AGE:

This input variable has four fuzzy sets namely “Minor”, “Young", “Middle”, Old". Membership functions of them are trapezoidal. Fuzzy sets Range of Age are identified in Table 5.

Table 5: Fuzzy Sets of Age (Source: Author's own work)

Input Field	Range	Fuzzy set
Age	<= 18	Minor
	18 - 35	Young
	35 - 65	Middle
	65 - 100	Old

Membership functions for fuzzy sets are identified in Figure 10.

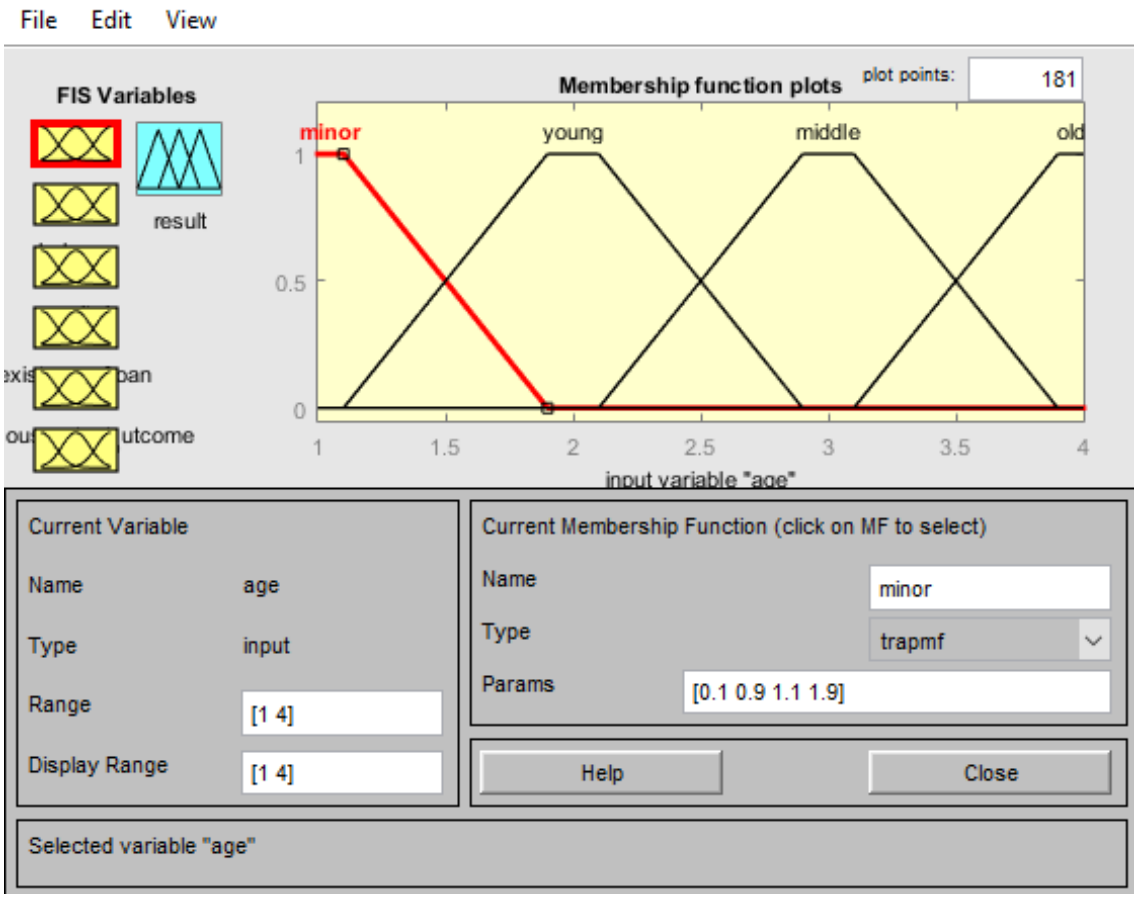

Figure 10 : Membership Functions for Age (Source: Author's own work)

6.1.3 BALANCE:

Balance is the average yearly balance that is available with the customer's bank. This input variable has three fuzzy sets namely "Low", "Average", "High". Membership functions of them are trapezoidal. Fuzzy sets Range of Balance are identified in Table 6

Table 6: Fuzzy Sets of Balance (Source: Author's own work)

Input Field	Range	Fuzzy set
Balance	<= 15000	Low Balance
	15000 - 100000	Average Balance
	100000 - 200000	High Balance

Membership functions for fuzzy sets are identified in Figure 11.

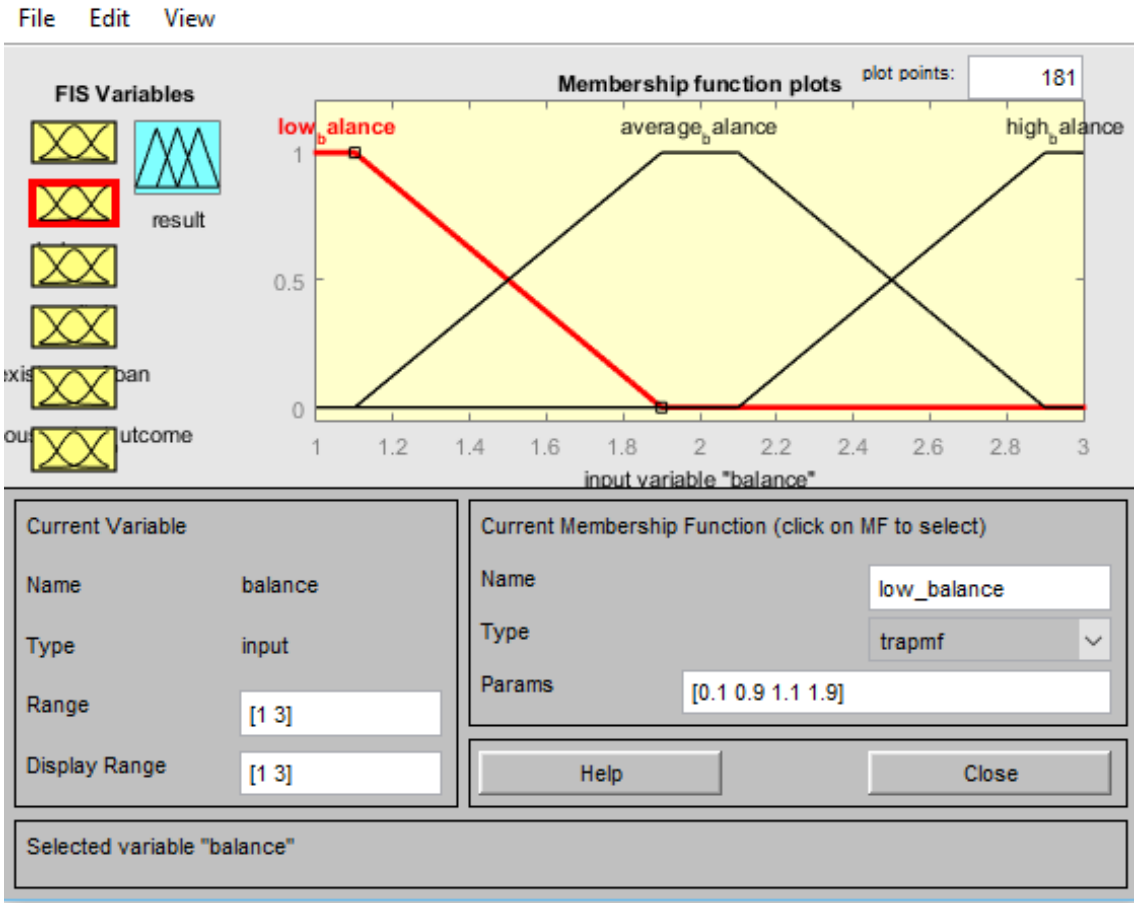

Figure 11: Membership Functions for Balance (Source: Author's own work)

6.1.4 **MARITAL**:

This input variable has two fuzzy sets namely “Married”, “Single”. Membership functions of them are trapezoidal. Fuzzy sets Range of Marriage are identified in Table 7.

Table 7: Fuzzy Sets of Marital (Source: Author's own work)

Input Field	Range	Fuzzy set
Marital	Single	Single
	Married	Married

Membership functions for fuzzy sets are identified in Figure 12.

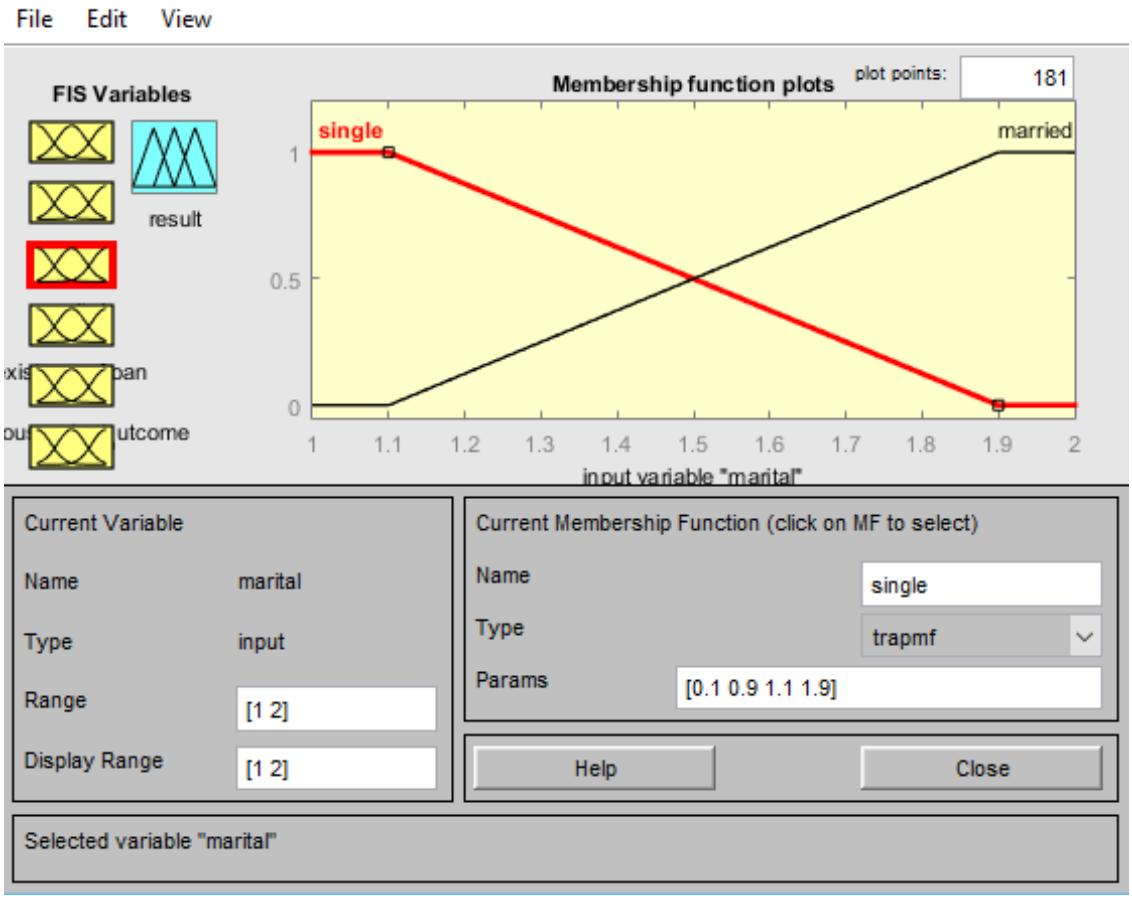

Figure 12: Membership Functions for Marital (Source: Author's own work)

6.1.5 EXISTENCE OF LOAN

This fuzzy set has three possibilities namely Low, Medium and High. This is described as high, medium or low amount of low. A record without any loan will be described within low only.

Table 8: Fuzzy Sets of Existence of Loan (Source: Author's own work)

Input Field	Range	Fuzzy set
Existence of Loan	0 - 20000	Low
	20000 - 100000	Medium
	<= 100000	High

The range is described in Table 8 and membership functions in Figure 13

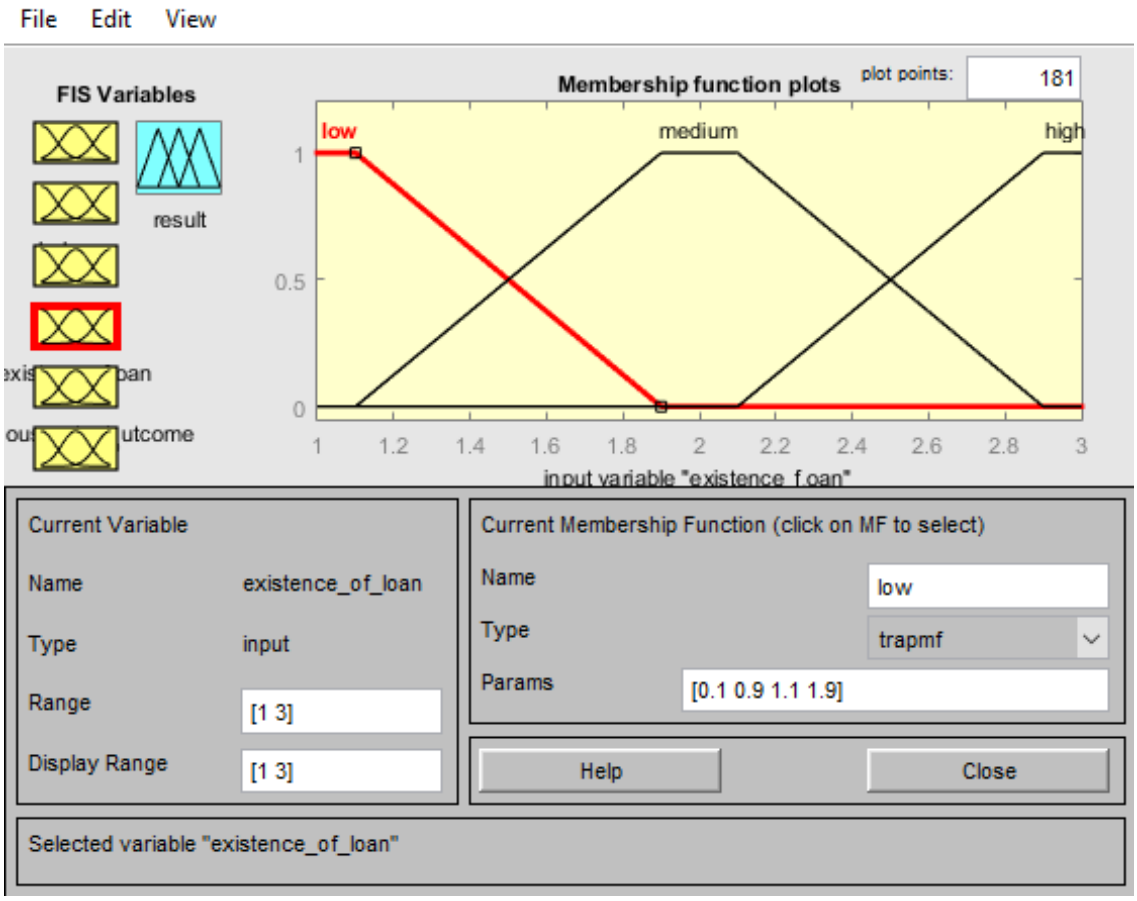

Figure 13: Membership Functions for Existence of Loan (Source: Author's own work)

6.1.6 PREVIOUS CONTACT OUTCOME

Previous contact outcome is the result of the previous campaign, whether the policy was bought or not. It has only two members, success or failure. For the range, we have Table 9.

Table 9: Fuzzy Sets of Previous Contact Outcome (Source: Author's own work)

Input Field	Range	Fuzzy set
Previous Contact Outcome	Success	Success
	Failure	Failure

And for the membership functions is on Figure 14.

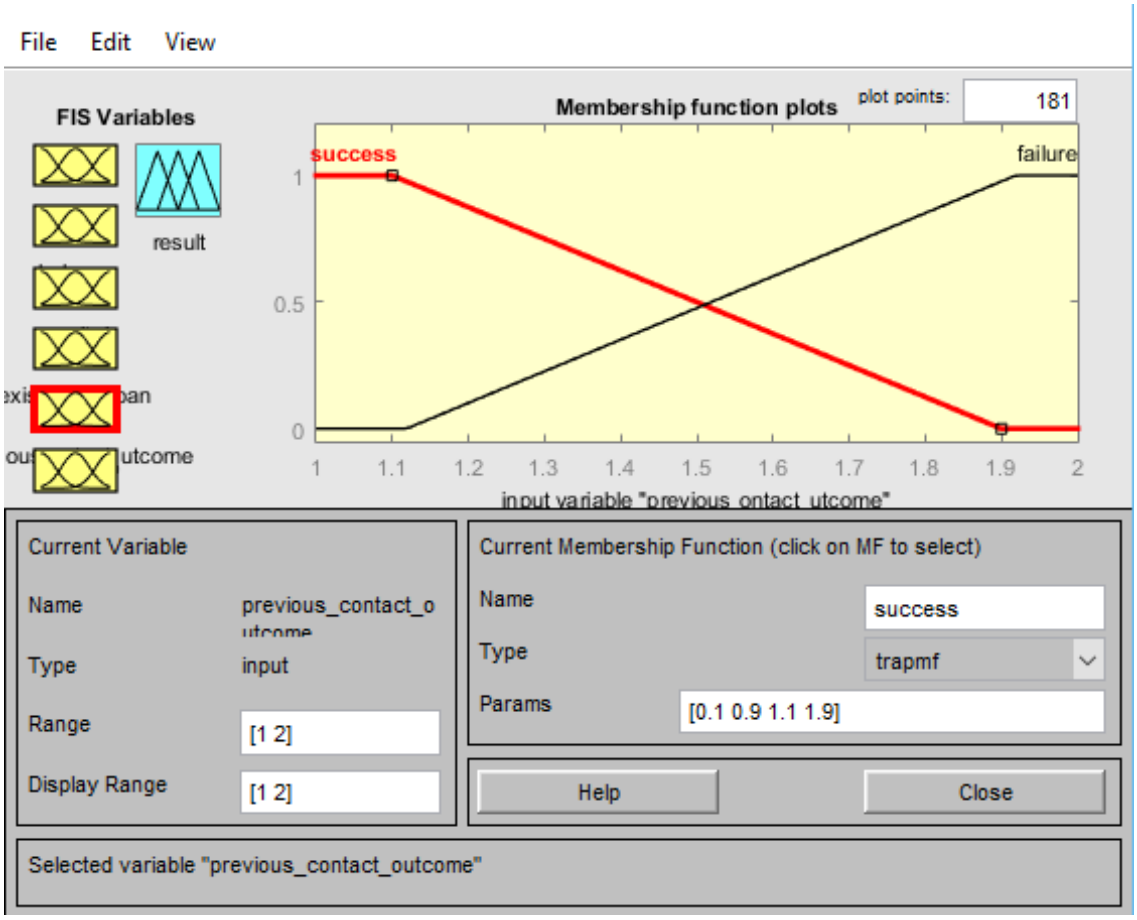

Figure 14: Membership Functions for Previous Contact Outcome (Source: Author's own work)

6.1.7 DURATION OF CONTACT

Duration of Contact is the duration of the last call made, which is in seconds. It has three attributes.

Table 10: Fuzzy Sets of Duration of Contact (Source: Author's own work)

Input Field	Range	Fuzzy set
Duration of contact	0 - 300	Low
	300 - 800	Medium
	<= 800	High

The range, again is described in Table 10 and Figure 15.

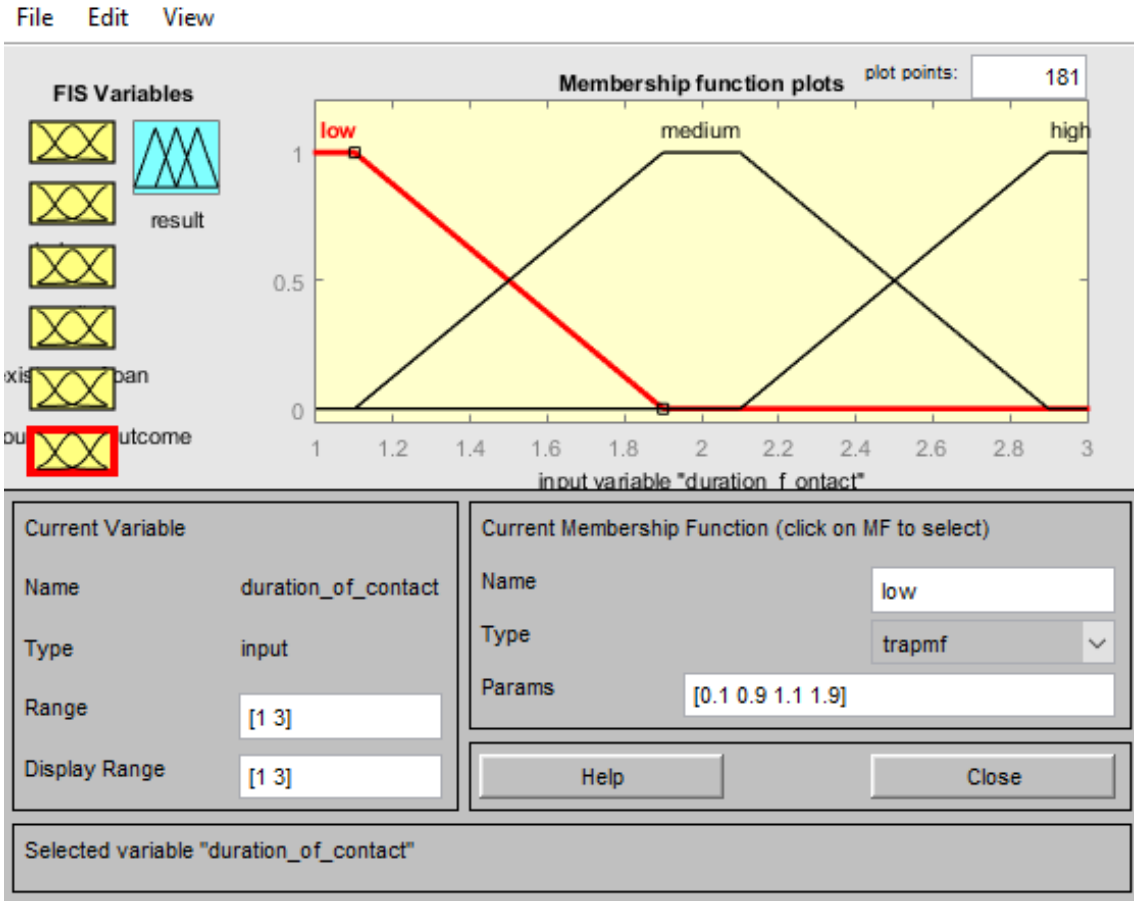

Figure 15: Membership Functions of Duration of Contact (Source: Author's own work)

6.1.8 DEPOSIT-SUBSCRIPTION

Output Variable is:

The purpose of the system is to identify the customers who will subscribe for the bank deposit. The output variable is in the form of three variables, high chance, very-high chance and low chance. Table 11 identifies these fuzzy sets and its range.

Table 11: Output Deposit-Subscription (Source: Author's own work)

Output Field	Range	Fuzzy set
Deposit Subscription Chance	0 - 0.4	Low Chance
	0.4 - 0.8	High Chance
	0.8 - 1	Very High Chance

The membership functions of the fuzzy sets are triangle which is depicted in Figure 16.

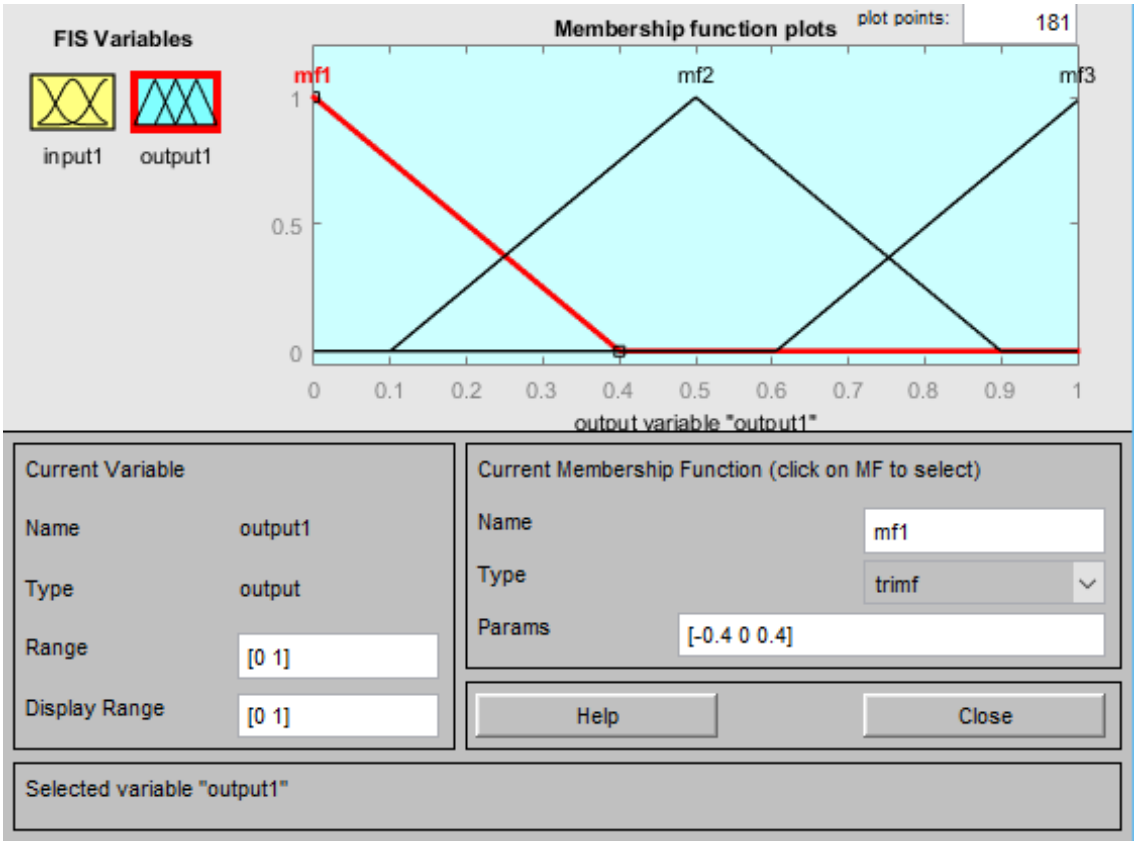

Figure 16: Output (Source: Author's own work)

6.1.9 Fuzzy Rule Base

The Rules Base has been determined after consultation with experienced bank advisor. From the discovered 648 fuzzy rules, we selected 100 rules randomly and presented them to the banking officials whom we also consulted on the definition of the linguistic terms. The rules were evaluated according to how useful and how unexpected they were, as judged by the domain expert. Our rule base consists of 9 rules that determine the deposit subscription status (Low Chance, High Chance and Very High Chance) by evaluation of the input variables mentioned above. The rule base is shown in Table 12.

Table 12: Fuzzy Rule Base (Source: Author's own work)

Rule Number	Age	Balance	Marital	Loan	Previous Contact Outcome	Duration of contact	Chance for Subscription
1	Young	High	Single	Low	Success	High	Very High Success
2	Young	High	Married	Low	Success	Medium	Very High Success
3	Young	Medium	Married	Low	Success	High	Very High Success
4	Young	High	Single	Medium	Success	Medium	Very High Success
5	Middle	High	Married	Low	Success	High	Very High Success
6	Middle	Medium	Married	Medium	Failure	Medium	High Success
7	Middle	Medium	Married	Medium	Success	High	Very High Success
8	Middle	High	Married	High	Success	Medium	Very High Success
9	Old	High	Married	Low	Success	Low	High Success
10	Minor	Low	Single	Low	Failure	Low	High Success
11	Young	Medium	Married	Low	Failure	Low	High Success

6.1.10 State Matrixs

Table 13: Fuzzy Rule Base State Matrix (Source: Author's own work)

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	0	1	1	0	
2	1	0	1	0	0	0	
3	0	1	0	0	0	1	
4	0	0	0	0	0	0	520

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	1	1	0	
2	1	0	0	0	0	0	
3	0	1	0	0	0	1	
4	0	0	0	0	0	0	540

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	1	1	0	
2	1	1	0	0	0	0	
3	0	0	0	0	0	1	
4	0	0	0	0	0	0	500

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	0	0	1	0	
2	1	0	1	1	0	1	
3	0	1	0	0	0	0	
4	0	0	0	0	0	0	470

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	1	1	0	
2	0	0	0	0	0	0	
3	1	1	0	0	0	1	
4	0	0	0	0	0	0	560

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	0	0	0	
2	0	1	0	1	1	1	
3	1	0	0	0	0	0	
4	0	0	0	0	0	0	420

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	0	1	0	
2	0	1	0	1	0	0	
3	1	0	0	0	0	1	
4	0	0	0	0	0	0	500

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	0	1	0	
2	0	0	0	0	0	1	
3	1	1	0	1	0	0	
4	0	0	0	0	0	0	480

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	1	1	1	
2	0	0	0	0	0	0	
3	0	1	0	0	0	0	
4	1	0	0	0	0	0	440

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	1	1	0	1	0	1	
2	0	0	1	0	1	0	
3	0	0	0	0	0	0	
4	0	0	0	0	0	0	280

	Age	Balance	Marital Status	Existence of Loan	Previous Contact Outcome	Duration of contact	
1	0	0	1	1	0	1	
2	1	1	0	0	1	0	
3	0	0	0	0	0	0	
4	0	0	0	0	0	0	390

6.2 Fuzzy based expert system in Matlab

To begin the process, our expert system analyse six key inputs.

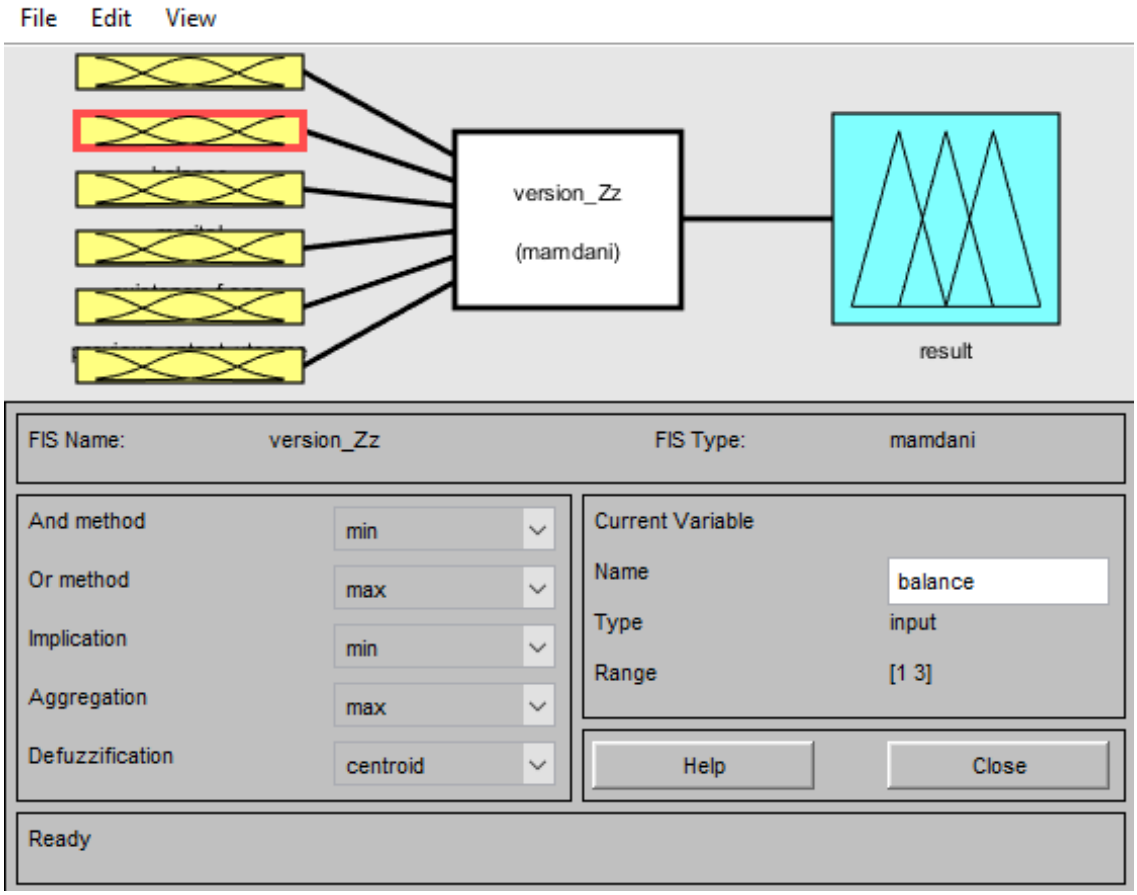

Figure 17: Fuzzy based expert system in Matlab (Source: Author's own work)

6.2.1 Fuzzification and Defuzzification

This system depends on Mamdani model for inference mechanism, in it and method is minimum (this system doesn't contains the ‘or’ operator), Implication method is minimum which involves defining the consequence as an output fuzzy set. Aggregation method between rules is maximum to combine the output fuzzy set. The Fuzzification method used is max-min and Defuzzification method is centroid.

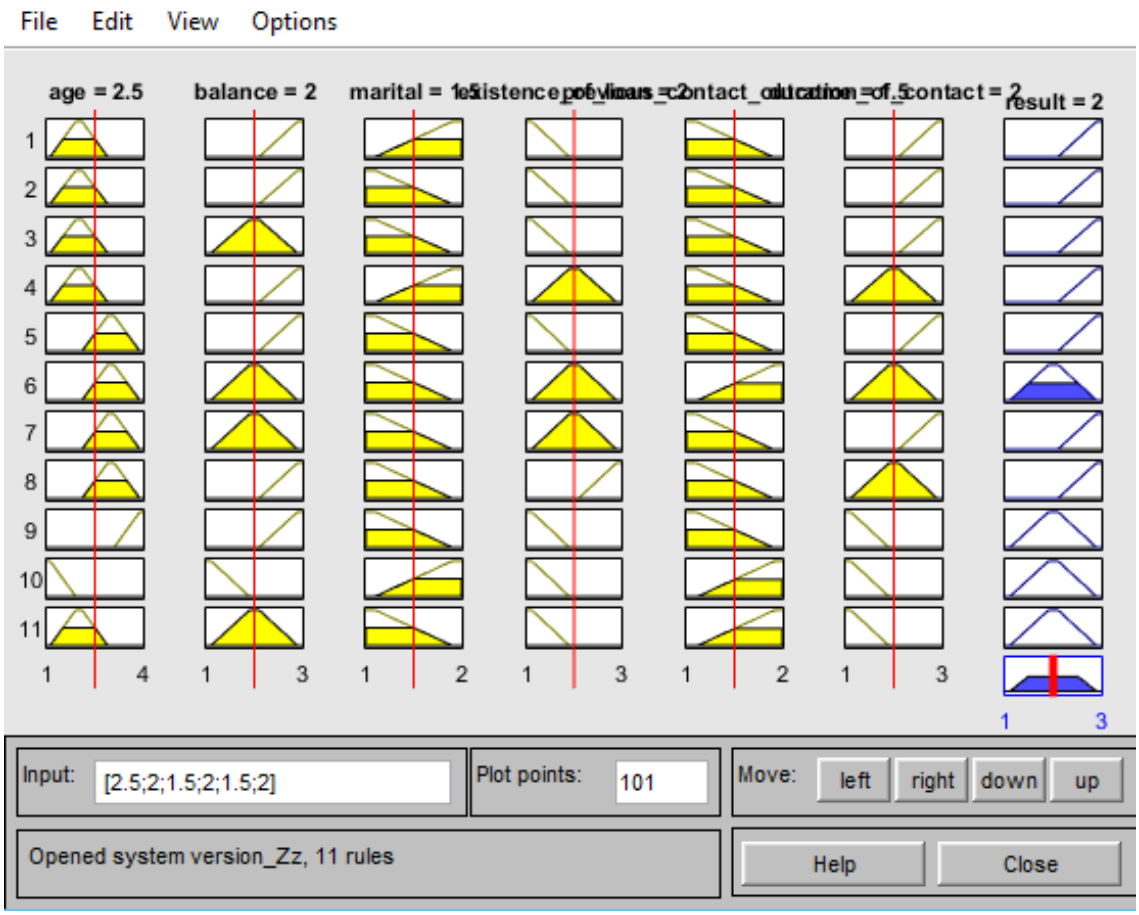

Figure 18: The results of tested (Source: Author's own work)

6.3 Test of the expert system

The test is done on a customer and her marital status is married and her available balance is high then that is very likely customer to go for fixed deposit scheme. The provided customer data was a person around 50 years of age, approximate saving around 2250 dollars per year, married, no previous loan, never contacted earlier by marketing person, duration of contact by marketing person around half an hour. These inputs represent the degree of vagueness/doubt in the information furnished during various time periods. The degree of vagueness/doubt in the information and the level of judgment used by the marketing person in deciding to approach this customer for subscribing the deposit scheme is always a challenge. At this type of situation fuzzy based expert system is a very good tool for decision making for both customer and marketing managers to invest on directed campaigns with a strict and rigorous selection of contacts.

CONCLUSION

The main goal of the master's thesis was to build up a fuzzy based expert system to improve decision making for direct marketing strategy and maintain customer's potential. Customer relationship management has a significant importance for companies to be successful on the market. Many organisations try to come up with new approaches to attract new customers meanwhile keep the old ones. The findings enhance our understanding of keeping current customers. The findings suggest that current customers are far cheaper than get new customers.

This paper describes design of fuzzy decision support system for identification of prospective customer in situations of data diversity and imprecision, which can be used by specialized banking experts for improving their marketing campaign. This study has shown that building up a model include many steps and this paper could be a basic manual which include essentials. Although this study focuses on the expert system, the findings may well have a bearing on quality of data. This research extends our knowledge about the importance of data which was also the major limitation of this paper.

Author's future efforts will be to use association rules that can produce an optimum surface representing all the combination points from a few of the tested combinations. Also further author would like to work on other areas for applying fuzzy logic.

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LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Appendix A – The part of System's code

Editor - C:\Users\Jan\Dropbox\Dissertation (Master's Thesis) MK1\Models\ZZ Model\version_Zz.m

scriptv2.m | Model_MK4v2 | readfis.m | evalfisv2.m | version_Zz.m

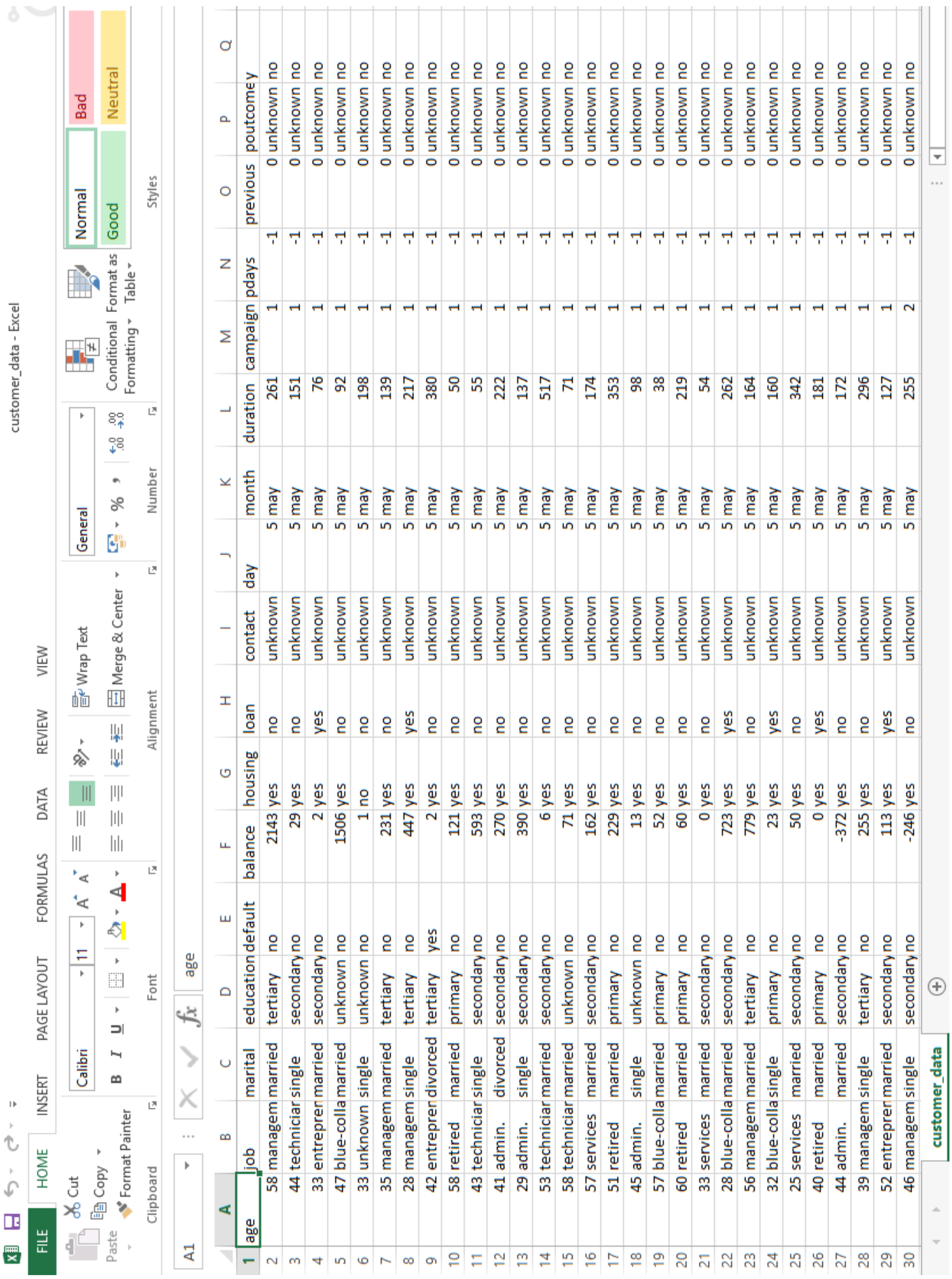
```
clc
clear all

age=input('Age: 1 - Under 18 (Minor), 2 - 18 to 35 (Young), 3 - 35 to 65 (Middle), 4 - 65 to 100 (Old)');
balance=input('Balance 1 - Under 15000 (Low Balance), 2 - 15000 to 100000 (Average Balance), 3 - 100000 to 200000 (High Balan
marital=input('Marital 1 - Single, 2 - Married');
existence_of_loan=input('Existence of loan 1 - Under 20000 (Low), 2 - 20000 to 100000 (Medium), 3 - Over 100000 (High)');
previous_contact_outcome=input('Previous contact outcome 1 - Success, 2 - Failure');
duration_of_contact=input('Duration of contact in seconds 1 - Under 300 (Low), 2 - 300 to 800 (Medium), 3 - Over 800 (High)')

fuzzymodel=readfis('version_Zz.fis');
result=evalfis([age balance marital existence_of_loan previous_contact_outcome duration_of_contact], fuzzymodel);

if result > 0 && result <= 1.5
    disp('Less chance');
end
if result > 1.5 && result <= 2.5
    disp('High chance');
end
if result > 2.5 && result <= 3.0
    disp('Very high chance');
end
```

Command Window

New to MATLAB? See resources for Getting Started.

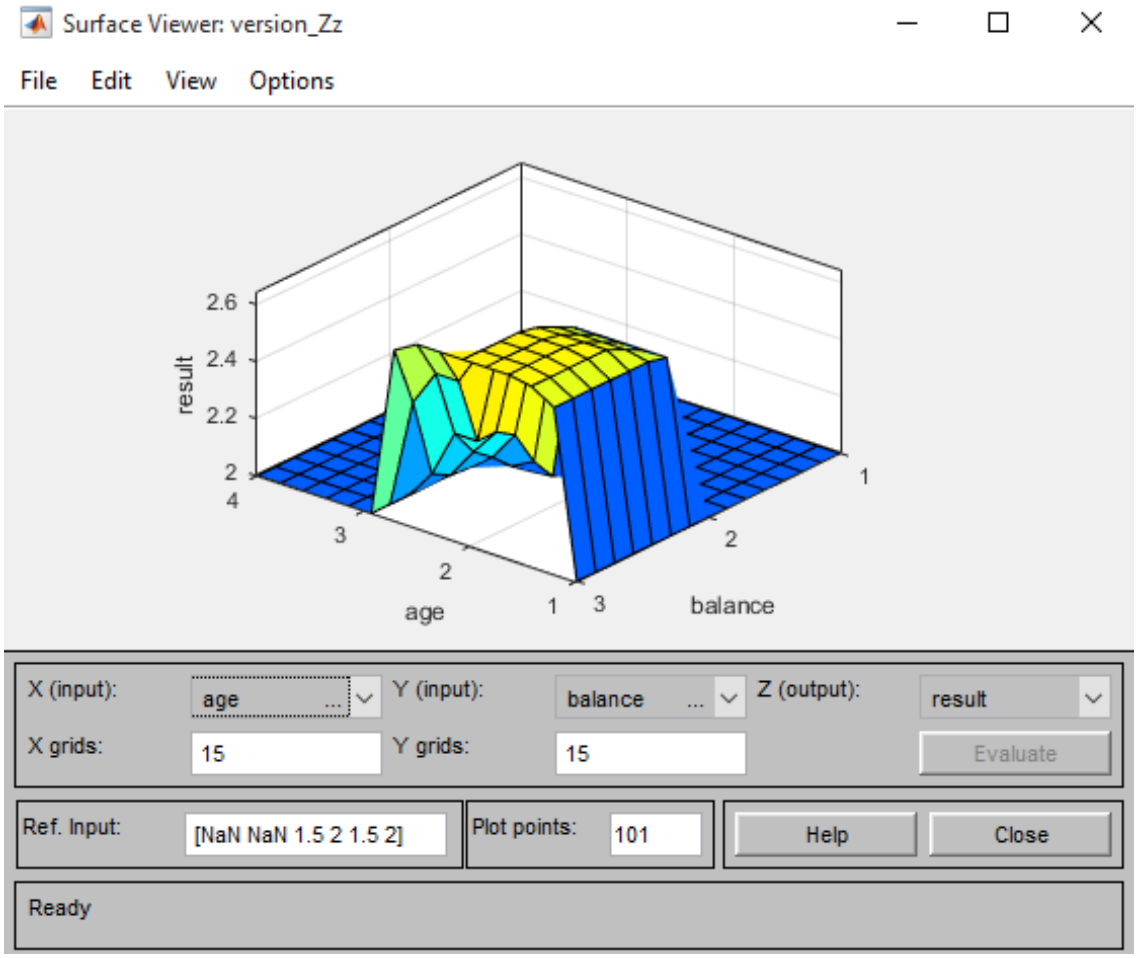
>>

Appendix B – Example of data in csv file

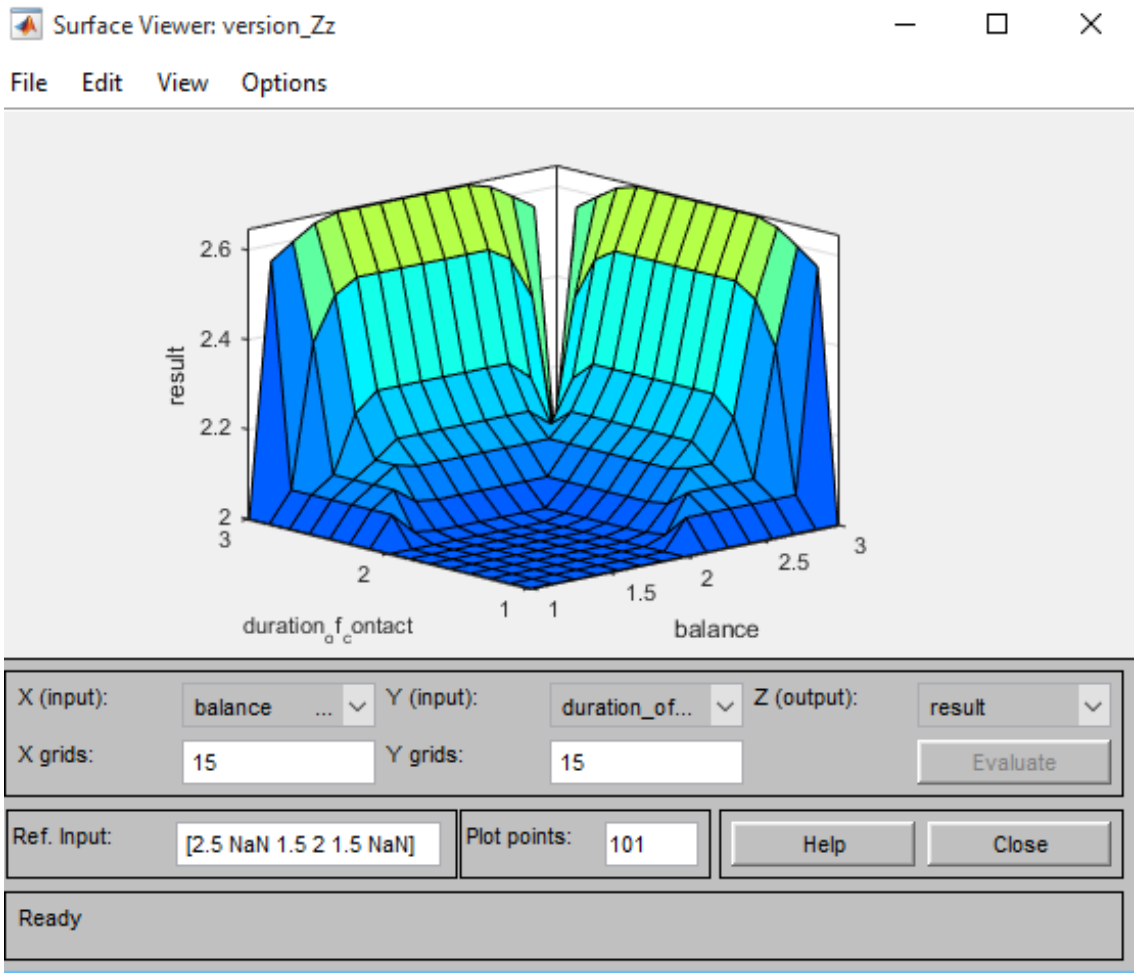


age	job	marital	education	default	balance	housing	loan	contact	day	month	duration	campaign	pdays	previous	poutcome	y
58	managem	married	tertiary	no	2143	yes	no	unknown	5	may	261	1	-1	0	unknown	no
44	technician	single	secondary	no	29	yes	no	unknown	5	may	151	1	-1	0	unknown	no
33	entrepren	married	secondary	no	2	yes	yes	unknown	5	may	76	1	-1	0	unknown	no
47	blue-colla	married	unknown	no	1506	yes	no	unknown	5	may	92	1	-1	0	unknown	no
33	unknown	single	unknown	no	1	no	no	unknown	5	may	198	1	-1	0	unknown	no
35	managem	married	tertiary	no	231	yes	no	unknown	5	may	139	1	-1	0	unknown	no
28	managem	single	tertiary	no	447	yes	yes	unknown	5	may	217	1	-1	0	unknown	no
42	entrepren	divorced	tertiary	yes	2	yes	no	unknown	5	may	380	1	-1	0	unknown	no
58	retired	married	primary	no	121	yes	no	unknown	5	may	50	1	-1	0	unknown	no
43	technician	single	secondary	no	593	yes	no	unknown	5	may	55	1	-1	0	unknown	no
41	admin.	divorced	secondary	no	270	yes	no	unknown	5	may	222	1	-1	0	unknown	no
29	admin.	single	secondary	no	390	yes	no	unknown	5	may	137	1	-1	0	unknown	no
53	technician	married	secondary	no	6	yes	no	unknown	5	may	517	1	-1	0	unknown	no
58	technician	married	unknown	no	71	yes	no	unknown	5	may	71	1	-1	0	unknown	no
57	services	married	secondary	no	162	yes	no	unknown	5	may	174	1	-1	0	unknown	no
51	retired	married	primary	no	229	yes	no	unknown	5	may	353	1	-1	0	unknown	no
45	admin.	single	unknown	no	13	yes	no	unknown	5	may	98	1	-1	0	unknown	no
57	blue-colla	married	primary	no	52	yes	no	unknown	5	may	38	1	-1	0	unknown	no
60	retired	married	primary	no	60	yes	no	unknown	5	may	219	1	-1	0	unknown	no
33	services	married	secondary	no	0	yes	no	unknown	5	may	54	1	-1	0	unknown	no
28	blue-colla	married	secondary	no	723	yes	yes	unknown	5	may	262	1	-1	0	unknown	no
56	managem	married	tertiary	no	779	yes	no	unknown	5	may	164	1	-1	0	unknown	no
32	blue-colla	single	primary	no	23	yes	yes	unknown	5	may	160	1	-1	0	unknown	no
25	services	married	secondary	no	50	yes	no	unknown	5	may	342	1	-1	0	unknown	no
40	retired	married	primary	no	0	yes	yes	unknown	5	may	181	1	-1	0	unknown	no
44	admin.	married	secondary	no	-372	yes	no	unknown	5	may	172	1	-1	0	unknown	no
39	managem	single	tertiary	no	255	yes	no	unknown	5	may	296	1	-1	0	unknown	no
52	entrepren	married	secondary	no	113	yes	yes	unknown	5	may	127	1	-1	0	unknown	no
46	managem	single	secondary	no	-246	yes	no	unknown	5	may	255	2	-1	0	unknown	no

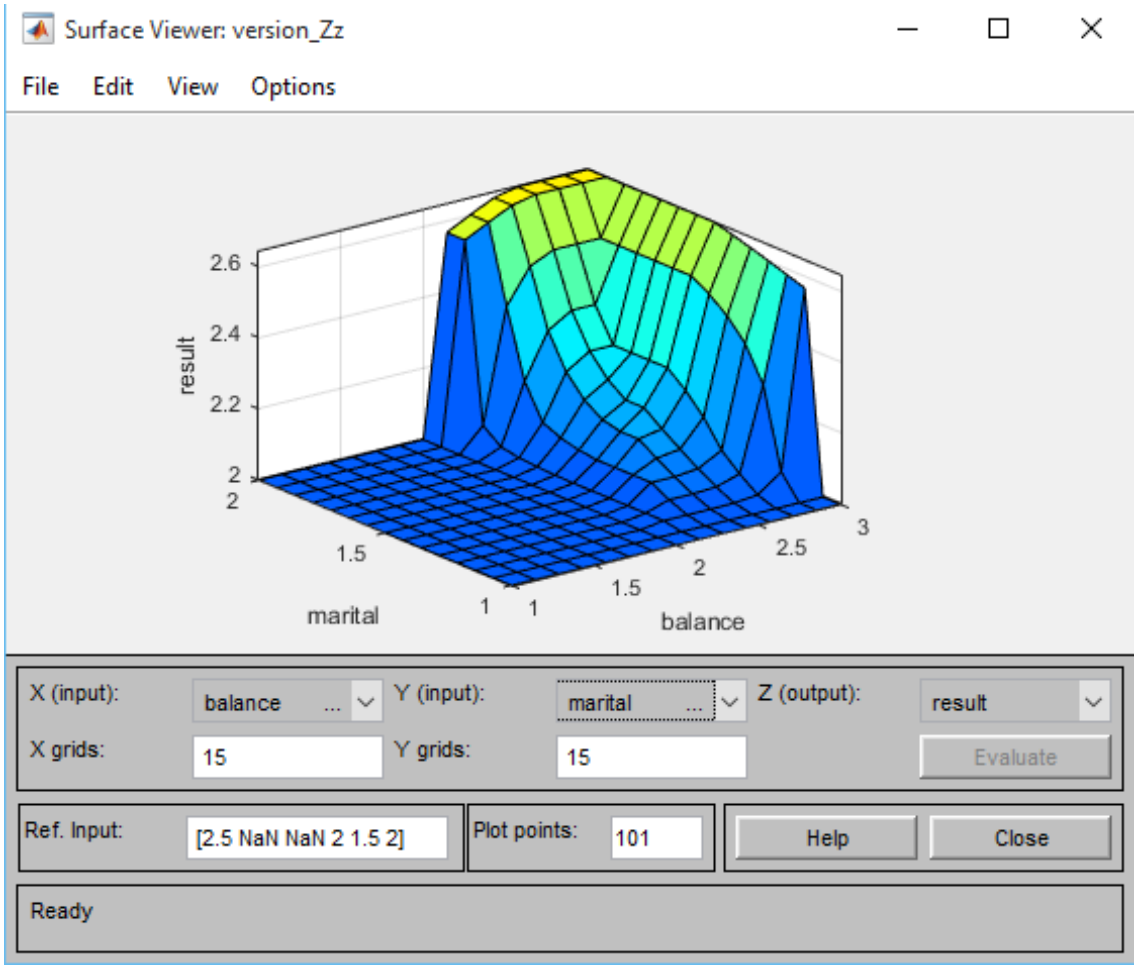
Appendix C – Graphical visualisation of the dependence of two input variables – age and balance



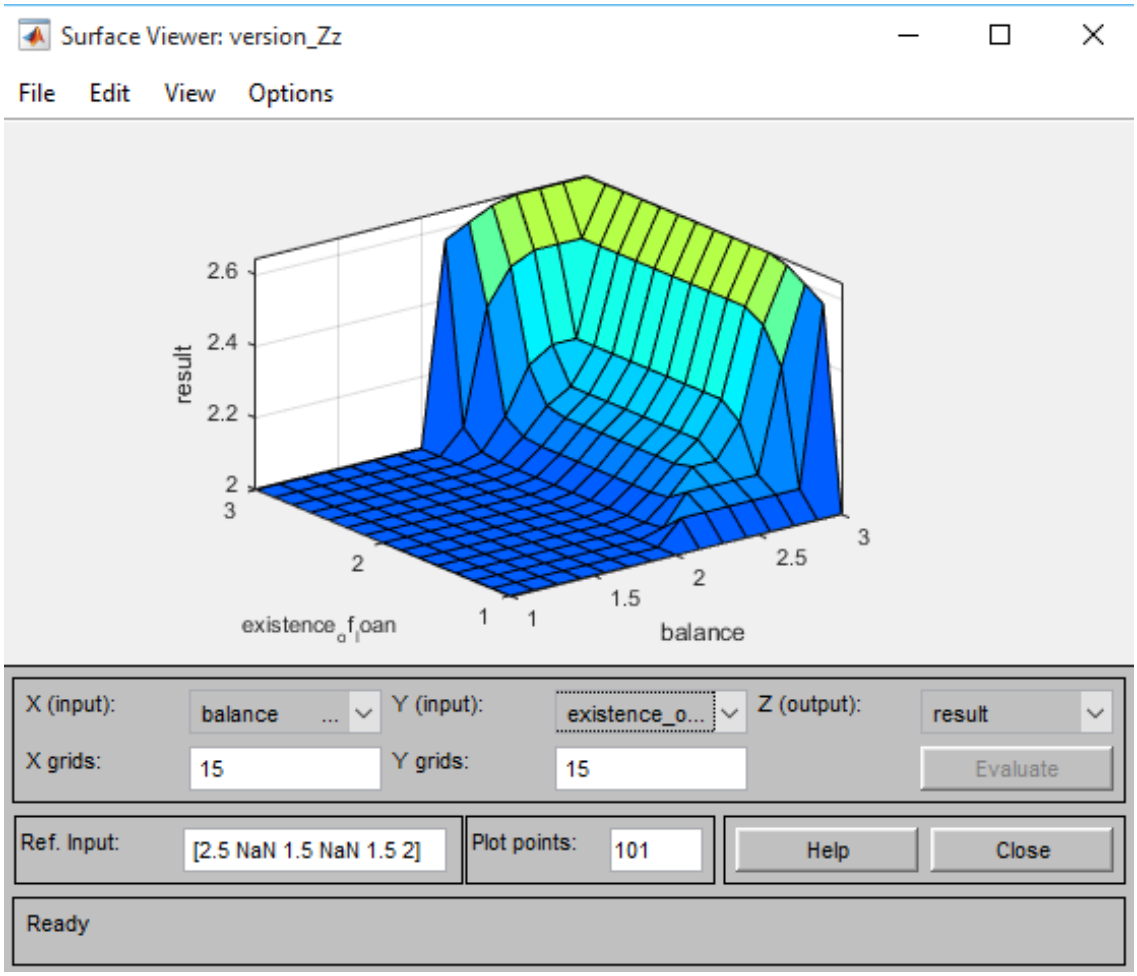
Appendix D – Graphical visualisation of the dependence of two input variables – balance and duration of contact



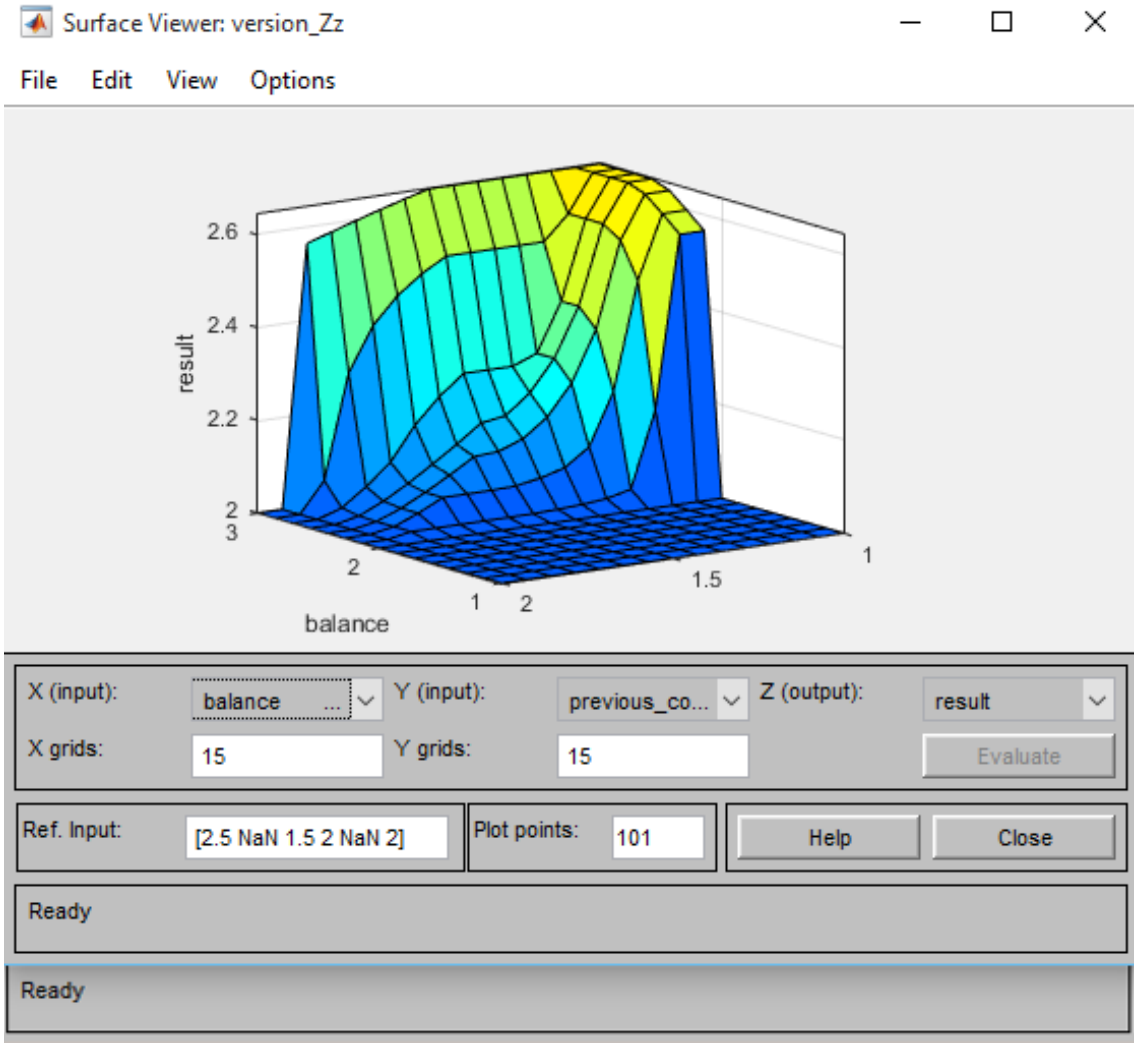
Appendix E – Graphical visualisation of the dependence of two input variables – balance and marital



Appendix F – Graphical visualisation of the dependence of two input variables – balance and existence of loan



Appendix G – Graphical visualisation of the dependence of two input variables – balance and previous contact



Appendix H – Graphical visualisation of the dependence of two input variables – duration of contact and age